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STRATEGIC MARKET PERSPECTIVE

Wireless Telecommunications Marketplace

U.S. Market Analysis Program

SEPTEMBER 1994

Wireless Telecommunications Marketplace

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Abstract

INPUT's *Wireless Telecommunications Marketplace* provides an overview of developments and opportunities available to services providers in the dynamic wireless communications market. The report discusses emerging technologies for wireless delivery, regulatory concerns for market participants and market drivers and inhibitors. The competitive climate is discussed, vendors' major issues described and buyer concerns and issues defined. Conclusions and recommendations are offered, and a glossary of wireless telecommunications terminology is provided.

The report has 102 pages and 33 exhibits

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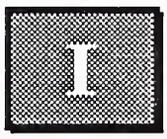


Introduction

A Purpose

The wireless industry is in the process of significant change. With major investments being made in an industry that is in the early stages of defining itself, risk is a significant factor—not only to vendors and venture capitalists, but to users who seek a competitive advantage through several advanced technologies that lack a clear definition of standards and are subject to changing government regulations.

INPUT has set out to analyze and describe the wireless data and, to a lesser extent, the wireless voice communications industry. It is a marketplace in which the only constant is change and double-digit growth. The objective of this analysis will be to provide an understanding of the concepts, technologies, events, trends, and issues that make up this marketplace. This should help to identify forces influencing vendors and users, determine actions that have been taken by vendors in developing new technologies, and assess user demand and how users are deploying wireless solutions.

The report also shows how the wireless industry integrates with the main-line telecommunications industry, which is also undergoing great change.

B Methodology

The report was developed through a combination of primary (direct interviews) and secondary research. Twenty-three in-depth interviews with user and vendor professionals from diverse

industries form the basis of the report. The interviews were aimed at identifying user purchasing motivation, decision processes and selection criteria for specific services, and identifying the actions taken by vendors to remain or become competitive in the marketplace.

Vendors of all sizes and disciplines were interviewed, including companies that only offered software or terminals. Special interest was focused on the carriers because they will probably have the greatest influence on how this industry evolves over the next five years.

Voice communications was included in the interview scope to ensure an accurate understanding of the basic market, because much of the wireless industry has been designed and created around the needs of users for this primary medium.

Financial data and business motivation information were obtained from users and vendors in order to gain an accurate profile of the buying habits and preferences of users, and the pricing and marketing strategies and practices of vendors.

The resulting data were analyzed for trends and interrelationships and converted into information reflecting the attributes and tendencies of users and vendors.

INPUT considers the samples used commensurate with the conclusions drawn, and has, where appropriate, adjusted the sample base to remove any undue bias that could result from unique or extreme responses, which could otherwise skew the findings.

C
Organization

The report is divided into nine chapters and three appendixes. The contents of each are as follows:

Chapter I, *Introduction*, introduces the report and explains its importance; defines report organization; explains scope of the report and the methodology used in gathering, analysis, and preparation of data and report findings; and identifies related INPUT reports.

Chapter II, *Executive Summary*, offers an overview of the analysis conducted as part of the study and summarizes report findings. It is a brief summation of the report's major topics and findings, suitable (in size and scope) for a senior executive who wants to understand the most important issues and conclusions without reviewing the entire study.

Chapter III, *Overview and Background*, examines the history and basic definitions of what wireless was and what it is becoming. It reviews this evolution, the ten ways to communicate currently through wireless, and notes some of the new reasons to use this medium.

Chapter IV, *Concepts and Technology*, reviews the concepts employed in wireless technology. It defines the six types of transmission configurations and systems components that are needed for wireless communication. Special attention is directed to the finite radio spectrum and its limitations as a usable commodity, and to ways to optimize the availability of the industry's valuable resources. Finally, there is a review of the types of products and service offerings in the industry, including transmission alternatives, mobile computing terminals, and supporting software.

Chapter V, *Wireless Marketplace*, looks at the trends, issues and events surrounding the marketplace. Areas in which major change is under way include the regulatory environment, where free market plans are being introduced, and the convergence implications of the larger telecommunications industry. Standards and the lack of them are reviewed. Market drivers and inhibitors have been identified as forces influencing the industry, and assessments are made of market direction and forecast expenditures in specific market areas.

Chapter VI, *Vendor Trends and Issues*, reviews the competitive climate among vendors, noting the business-driven trends and issues as well as the technological issues and impacts of major breakthroughs. It notes key growth promoters, inhibitors, and market strategies.

Chapter VII, *User Trends and Issues*, discusses users' responses to INPUT's interviews. Specific trends, concerns, and issues are reviewed.

Chapter VIII, *Key Industry Applications*, looks at three key applications that are becoming significant in the wireless industry.

Chapter IX, *Conclusions, Recommendations, and Opportunities*, offers INPUT's conclusions and recommendations for three time periods: today; two to three years from now; and five to seven years from now. It also reviews some hot technologies and companies to watch.

Appendixes A, B, and *C* provide guides to terminology and key vendors, and copies of the questionnaires used in conducting the interviews.

D
Related INPUT Reports

INPUT publishes several other annual telecommunications-related reports. Reports of possible interest to the reader include:

- *Telecommunications Vertical Market Analysis, 1993-1998.* This report identifies key trends and issues affecting information services in the telecommunications marketplace, including telephone, cable TV, and broadcast service providers.

- *U.S. Network Services Market Forecast, 1993-1998.* This report is part of a series of annual market analysis reports that review network applications services, including value-added networks, EDI, and electronic information interchange; and electronic information services that address on-line data bases and news services.

- *Client/Server Applications Trends—Telecommunications Vertical Market Analysis, 1994.* This is one in a series of reports analyzing the trends in client/server applications by vertical market industry.

II

Executive Overview

This section provides an overview of the analysis conducted as part of this study. It provides a brief summarization of the report's major topics and findings, suitable in size and scope for the senior executive who wants to gain a succinct understanding of the most important issues and conclusions.

A Overview

The wireless industry is comprised of a number of carriers and terminal and software vendors. Often the industry is either described by identifying five or six carrier services or defining the types of terminals used. It tends to become confusing when one realizes that wireless is destined to support all applications, including voice, data, image (fax), and video, over several different configurations of radio systems, including broadcast and cellular designs.

1. Carrier Systems

The 10 wireless carrier systems include:

- Cellular Telephone
- SMR & ESMR (Specialized Mobile Radio/Enhanced)
- PCS (Personal Communications Services)
- PPN (Private Packet Networks)
- Paging and EPS (Enhanced Paging Services)

- Satellite and LEO (Low Earth Orbit)
- LANs (Local-Area Networks)
- PBXs (Private Branch Exchanges)
- Meteor Burst
- Other Private/Public Radio Systems

Each of the carrier systems has evolved, or is in the process of evolving. from a wireless transmission technology and a primary media focus. (See Exhibit II-1, Wireless Player Evolution.)

Exhibit II-1

Wireless Player Evolution

Wireless Carrier	Initial Business Objective	Initial Media Focus
Cellular Telephone	Expansion of mobile tele- phone	Voice
SMR	Taxi/Truck Dispatch	Voice
PCS	Next Step in Wireless	Voice/Page/Data/Fax/Video
PPN	Field Service Coordination	Data
Paging	Paging	Tone
Satellite	Voice/Data Messaging	Voice/Teletype
LAN	Local Data Networking	Data
PBX	Local Voice Switching	Voice
Meteor Burst	Messaging	Data
Other Radio Systems	Public & Private Comm	Voice/Teletype

Cellular Telephone

Cellular systems have been evolving for 10 years and provide predominantly voice and some data capabilities through mobile and portable wireless devices to their 13 million users. Cellular systems are usually marketed on a duopoly concept and rely on telephone companies, including RBOCs like Ameritech and US West, combined with non-telephone companies like McCaw

Cellular. Data is being passed over these analog systems today, but there is considerable room for improvement in quality and integrity.

Specialized Mobile Radio/Enhanced Specialized Mobile Radio

Specialized mobile radio got its start in the taxi cab and truck dispatch industries. In 1993, the FCC authorized the expanded use of this area, using a newly developed digital technology created by Motorola. Motorola sold off over 2,000 operating licenses to Nextel Communications (the most visible provider), CenCall (now OneComm), and Dial Page. This represents the beginnings of another nationwide wireless network. Other major investors include MCI, Comcast, and NTT. Enhanced SMR offers voice, paging, and data through one mobile handset.

Personal Communications Services (PCS)

PCS does not yet exist in this country and will probably take up to two years to roll out. The FCC has given this wireless service a very broad definition of services and devices addressing voice, data, image, and video. PCS will use a similar method of transmission to that of cellular telephone. However, because PCS is based on a subwatt (milliwatt) power concept, it will require many more cellular repeaters in a given (very likely a metropolitan) area than current cellular technology.

Private Packet (Radio) Networks (PPN)

There are two primary players in the PPN arena. The first is Ardis, which is a joint venture of IBM and Motorola, developed originally to support IBM field and customer engineers. The other PPN is called RAM Mobile Data and is comprised of RAM Broadcasting and the RBOC, BellSouth. Both offer two-way data communications and E-mail messaging over special handheld devices, and operate primarily in metropolitan areas.

Paging and Enhanced Paging Service (EPS)

Paging is considered a mature industry and offers cheap and reliable one-way service. Paging devices are now a commodity item (even with alpha-numeric messaging) where market differentiation is determined by price and geographic coverage. Enhanced paging takes this process into the realm of two-way

activity, allowing users to respond with a positive receipt of message acknowledgement.

Satellite and Low Earth Orbit (LEO)

Satellites are very costly, but offer much greater geographic coverage potential than terrestrial-based repeater and cellular systems. The need for ubiquitous communications in more remote areas will continue to drive this market. Some vendors get around these heavy investment costs by leasing a portion of a satellite. Other vendors are planning LEO satellites, which are considered to be high risk and very expensive because they require multiple satellites and require the usage and acceptance by all countries of the same frequencies.

Local-Area Networks (LANs and Wireless

Wireless LAN data rates vary from 19.2 Kbps to 20 Mbps, with effective transmission distances of up to about 800 feet. Most of these LAN transmitters are not required to be licensed by the FCC because they are considered to be "local" systems that operate strictly within the confines of a given installation. Some of them use infrared frequencies that restrict them to passing signals that are only line of sight. The systems operate using very low power and several different transmission technologies, including spread spectrum and narrow band.

Private Branch Exchanges (PBXs) and Wireless

Telephone switch (PBX) vendors are approaching wireless with at least two primary offerings. The first is a "local" system that operates like the LANs noted above, and includes very light weight telephone handsets with extended battery life. These systems operate in the unlicensed portion of the PCS band.

The second system is designed to integrate cellular and PBX telephone systems on a wireless basis. The benefits include a portable telephone that works at the office, as well as cellular applications, but the detriments include additional costs for wide-area air time and monthly service fees.

Meteor Burst

Using the passive reflector approach, meteor burst is a less expensive way to communicate across all parts of the country

without the aid of satellites and earth stations. It uses radio signals that are bounced off meteor trails to exchange two-way messages. Although it might take longer for data to reach its destination, it is a very reliable method supporting large geographical areas.

Other Private/Public Radio Systems

There are several other private radio systems, many of which have been the mainstay of business and government for many years. These applications range from systems like GMRS (General Mobile Radio Service) to the mobile air telephones in commercial airplanes.

2. Wireless Terminals

Apart from the traditional cellular telephone, there are several types of wireless data terminals, including some that have voice capabilities. These data terminals or mobile computers are largely the result of design compromises due to packaging, computing technologies, and limited battery life. The categories include:

- Paging and Enhanced Paging Devices
- Subnotebook Laptops
- Hybrid Pen Notebook Laptop Computers
- Personal Organizers, Palmtops, and Specific Application PCs
- Personal Communicators
- Personal Digital Assistants

Enhanced Paging Devices

The precursor to mobile computing and wireless applications was, and still is, the paging device. Paging devices have vibrating alarms and alpha-numeric displays that can receive multiple, limited-character E-mail messages. Also, rollout for acknowledged message receipt (two-way paging) will occur this year.

Subnotebook Laptops

These devices have become one of the primary mobile computing devices because they are so similar to traditional PCs and laptops. Given this software and computing design commonality, it has become a logical choice for on-the-road communications.

Hybrid Pen Notebook Laptop Computers

Certain applications like insurance adjustment have driven the development of pen-based systems which, until recently, used the pen-based interface to identify various parts of automobiles.

Palmtops

Palmtop computers perform all the functions of a personal organizer and reflect the need for a very small computing device. While sacrificing capability for smaller size, they provide personal calendaring, note taking, and calculator functions. The palmtop uses a DOS operating system and an E-mail communications interface.

Personal Communicators

These devices couple pen computing and fax transmission with voice cellular telephone capabilities. Vendors are considering the implications to Windows compatibility. Having the ability to run Windows software and communicate through data, fax, or voice media should be of significant interest.

Personal Digital Assistants (PDAs)

PDAs are more sophisticated than personal communicators because they include the computing power of a PC, but rely on pen-based entry. These devices are very versatile in information management, can support one-way messaging, and are expected to be able to perform two-way messaging later this year.

3. Software and Integration

The software supporting wireless applications has expanded far beyond dumb terminal emulation, having now evolved into three separate areas:

- User
- Middleware
- Services

User

Software supporting this area tends to address the remote control of wireless connections into various applications. This type of software supports data access and E-mail messaging, and re-extends the LAN's connection to the mobile computer.

Middleware

This area supports developers who need a way to create their own wireless interfaces and applications or interfaces to private packet networks like RAM and Ardis or Cellular's CDPD. Also, APIs (applications program interfaces) have been developed to simplify the communications interface, relieving the developer to focus on the application.

Services

These services provide wireless messaging services with gateways to Compuserve, AppleLink, and Internet. Some vendors have built software products that operate through the RAM and Ardis networks, as well.

B
Wireless Marketplace

The wireless marketplace is a very fast-paced business which requires vendors and users to keep track of its evolution. It is becoming more and more challenging to keep track of the many changes that are occurring. Especially now that there are at least 10 different ways to send the traditional voice, data, image (fax), paging, and video information via wireless transmission. Many of these 10 ways are capable of sending multiple forms of communication media. The following review summarizes some of the more important activities that are currently influencing the industry.

1. Regulatory Environment

A major effort is under way to rewrite the Communications Act of 1934. This legislation seeks to make major changes in how the telecommunications industry is run. Plans are under way to reduce regulation and create open markets. These pending changes are the result of rapidly changing technologies, changes in the way the U.S. and the world conducts business, and coming to the understanding that free markets now work better than regulation does when it comes to keeping costs down and productivity up.

There is a great deal of turmoil regarding rewrite activities. Some of it concerns a number of questions about how $30 billion to $50 billion involving local access fees will be potentially re-allocated. Much of what is relevant to these discussions has to do with how wireless (and other media) would be used to circumvent local exchange carriers. The entire industry—including all of the local exchange carriers and RBOCs, long-distance companies, and cable TV companies—will be affected.

2. Regulation versus Free Market

The FCC envisions that the PCS area will carry a large part of the wireless requirement. A license auctioning process conducted by the FCC could occur in the latter half of 1994, creating upwards of $7 billion for the FCC and the U.S. Treasury. The new PCS spectrum is more than three times greater than the current cellular telephone spectrum. The FCC is currently grappling with the issues of fair and equitable distribution of radio frequency spectrum.

3. Convergence Implications

The wireless industry sees the enactment of this rewrite legislation as a very important opportunity. Because the legislation encourages local bypass of RBOCs and other local exchange carriers, this provides a new incentive for cellular and PCS carriers to directly connect to the long-distance carriers. Obviously, cellular prices will have to come down to be competitive with local "hardwired" rates.

Everyone in the telecommunications industry wants to participate in the PCS auction, including many of the wireless carriers.

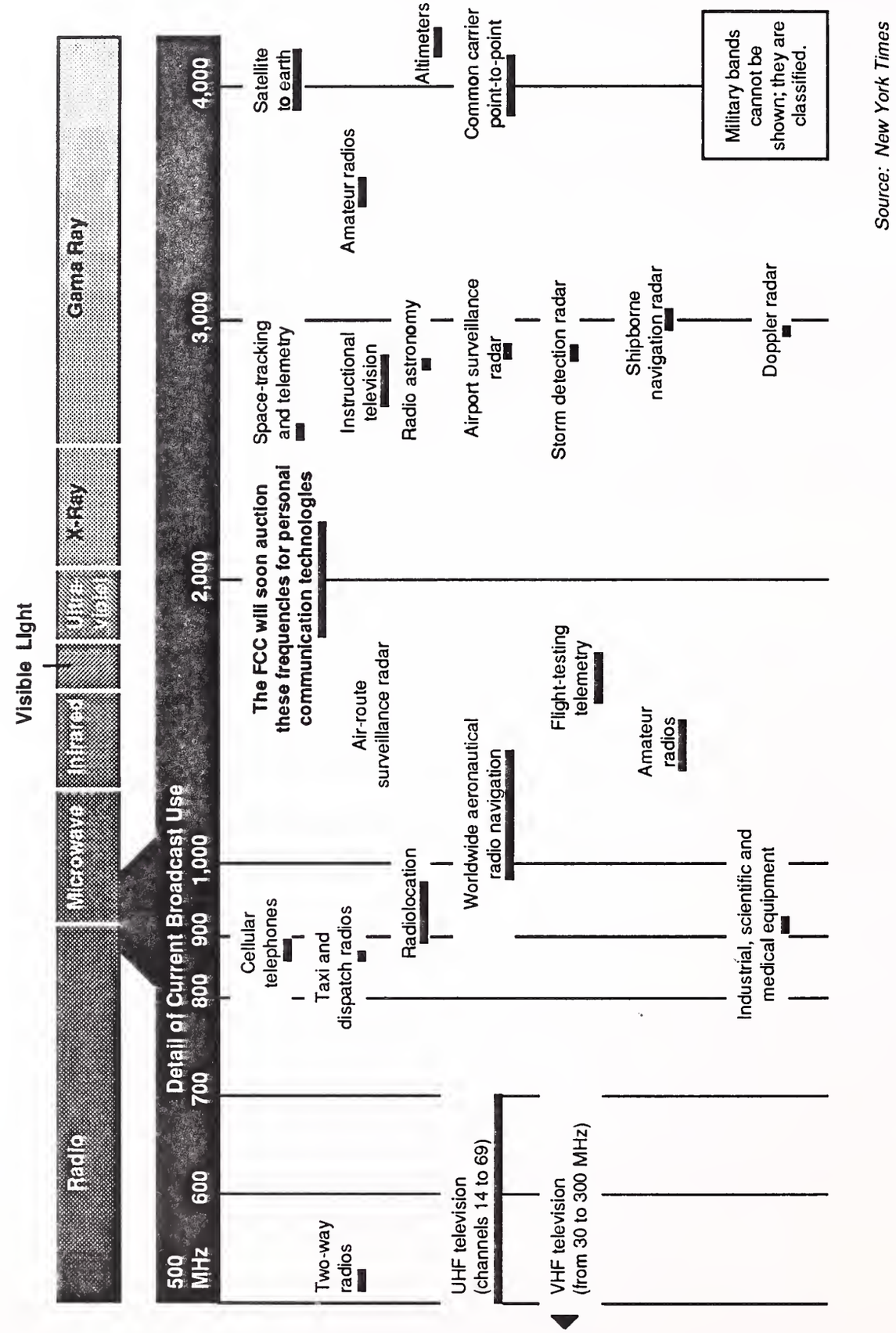
4. Radio Spectrum—A Finite Medium

The radio spectrum is a limited medium that is controlled by the Federal Communications Commission. Exhibit II-2 shows how the FCC has allocated the portions of the frequency spectrum that are relevant to cellular, private packet networks, and PCS (personal communications services).

Various transmission technologies have evolved over the years that attempt to conserve the amount of space (frequencies) required to hold a conversation. The point to be made is that we are encroaching on the limits of the fixed "commodity" or radio spectrum. It is not as easy to increase the capacity of a radio system as it is with hard-wired systems. There, capacity problems are easily overcome by installing more cable in the same conduit.

Exhibit II-2

Frequency Spectrum



Source: New York Times

5. Digital Multiplexing—TDMA versus CDMA

There are two digital multiplexing approaches used in the cellular industry to conserve spectrum and increase the number of simultaneous calls. Several organizations are behind a standard called TDMA, or Time Division Multiple Access. The end result of this different approach works out to be about a 7- to 9-channel improvement over one of today's analog channels.

CDMA, or Code Division Multiple Access, uses a new scheme that distributes a conversation over multiple channel frequencies (within a given cell). It is capable of providing as much as a 20-channel improvement over today's analog channels.

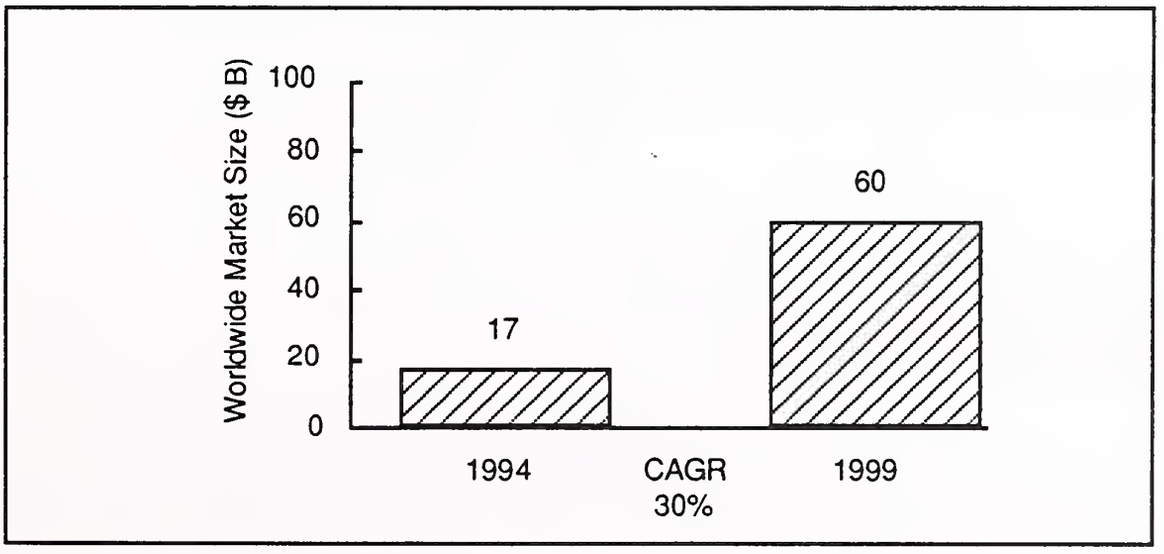
6. A Cellular Data Transmission Alternative—CDPD

Though TDMA and CDMA will help increase the number of voice channels in a cellular system, both alternatives currently do not support data transmission. The cellular industry plans to introduce a data transmission technology called CDPD. Cellular Digital Packet Data was developed by a consortium of Cellular operators and will be implemented over the next two to three years.

INPUT evaluated the total market for wireless equipment and service to be dramatically expanding at a 30% CAGR, as shown in Exhibit II-3.

Exhibit II-3

Worldwide Wireless Telecomunications Equipment and Services Market, 1994-1999



C
Market Drivers and Inhibitors

The wireless market drivers indicate that the industry is fast paced and very competitive. There is a demand for communications capability in many old and new applications. Major players are making significant investments in a high-stakes industry that is in the process of being invented.

Exhibit II-4

Market Drivers

- Demand for Ubiquitous Communications
- Competitive Business Climate
- Fast-Paced Micro-Technology Evolution
- Major Investments by Large Players

There are a number of potentially unfavorable market inhibitors, as shown in Exhibit II-5. They include unfavorable FCC auction decisions, lack of radio spectrum, standards which have to be defined, security issues in data transmissions, health hazard issues, and the potential of an industry shakeout. These are the good news/bad news items of a fast-paced technology evolution.

Exhibit II-5

Market Inhibitors

- Unfavorable Regulation
- Lack of Radio Spectrum
- Lack of Standards
- Security Issues
- Potential Health Hazard
- Fast-Paced Technology Evolution

D
Vendor Trends and Issues

Vendors indicated several trends and issues during the interview process. They indicated that the two most important business-driven trends were the needs to understand what the user really

needed and to find a way to share the risks of development and competition.

Exhibit II-6

Key Business-Driven Trends and Issues

- Understanding User's Needs
- "Co-Opposition"- Risk Sharing Alliances
- FCC Regulations
- Standards
- High Cost of Capital and Competition
- User Privacy Issues
- Wild Card Health Issue

Vendors indicated that the primary technology issues (see Exhibit II-7) involved wireless integration with other devices and software and the move towards digital multiplexing and data transmission.

Exhibit II-7

Key Technology Issues

- Integration
- Move to Digital Mutiplexing
- Global Deployment
- PCS Will Have To Do What Cellular does

Key growth promoters for vendors (shown in Exhibit II-8) included the emergence of new technologies and how they pressure competitive pricing, and increasing pace of acceptance by wireless users.

Exhibit II-8

Key Growth Promoters

- Emerging Technologies Pressure Competitive Prices
- Cellular Industry Maturing
- Product Availability and Market Awareness
- PCS Will Cause Market Expansion

Delays in product and/or service rollout, coupled with a market that is evolving very rapidly, can make for slow, or at best risky, growth. Vendors have to take into account that anticipated market returns may be squelched by delays in rollout, or by breakthrough technologies inserted into the marketplace by competitors which shorten a product's or service's life. Major inhibitors are shown in Exhibit II-9.

Exhibit II-9

Key Growth Inhibitors

- Delays in Product/Service Rollout
- Market Evolving Too Rapidly
- Shakeout Inevitable
- Cost of Equipment and Services
- Technology Integration and Compatibility Issues
- Wild Card Health Issue

The best strategy is one that stays in tune with the fast pace of the marketplace and what users really want. And it certainly helps to mitigate one's risk by sharing in the financial and technological development of new products and services. (See Exhibit II-10)

Exhibit II-10

Vendor Market Strategies

- Maintain Awareness of Fast-Paced Marketplace
- Know What Users Want
- Seek Carefully Selected Partnerships —"Co-Opposition"
- Seamless Networks (Carriers)

E
User Trends and Issues

Users can now see new ways to automate applications when the hard-wired umbilical cord is replaced with wireless as shown in Exhibit II-11. All of the users that were interviewed indicated that their installed or soon-to-be-installed wireless systems were mission critical. This represents an excellent vote of confidence for the wireless business.

Exhibit II-11

User Trends

- Wireless Will Be The Automation Enabler
- Demanding Improvements in Customer Service
- Wireless Rollout Plans—Project Management Responsibilities
- Search for Strategic Benefits

What concerned users most (see Exhibit II-12) was a lack of one-stop-shopping when it came to implementing wireless systems that required greater geographical coverage. Also, network interoperability and security ranked high on their list of concerns.

Exhibit II-12

User Concerns

- No One-Stop Shopping
- Network Interoperability, Security, and Voice Capability
- Health Hazard Implications

F
Conclusions and Recommendations

Keeping an eye on the big-picture perspective of the overall telecommunications industry will be beneficial to those who consider themselves participants in the wireless arena. Awareness of each player's goals, objectives, and affiliations will help to determine the optimum strategy when it comes to wireless products and services.

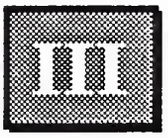
The wireless industry would experience serious setbacks if it is found that handheld devices do cause, or contribute to causing, cancer. Companies need to understand the issues and adopt proactive policies that are in compliance with all published FCC and FDA standards.

Systems integrators should continue to find fertile ground in the wireless industry. Vendors may find some additional alliance opportunities and outsourcing through these channels.

Simplicity, alliances, and open standards may become primary forces in the consolidation of various wireless products and

services. The company(ies) that come up with a single handheld and/or mobile device that integrates voice, data, and paging will wield considerable force. The ESMR and cellular industries appear closest to this unified solution.

Watch for the breakthrough technologies that may suddenly enable a new application and/or reduce its cost. The only constant is change in today's wireless industry.



Overview and Background

A
Overview

Almost one hundred years ago, wireless transmissions became possible. (See Exhibit III-1.) And, as with any new technology that seemed to imply the need for mirrors and smoke, people were a bit skeptical, to the point of seeing no need for such a system. In retrospect, the wireless phenomenon was probably easier to accept in that 'hard-wired' telegraph had existed for a number of years prior to this announcement.

At the turn of the century, mobile communications had made its debut. (See Exhibit III-2.) Antenna systems were a challenge for wireless developers, because many of the frequencies they operated on were below 1 megaHertz (MHz), requiring very large arrays. Little was known about the benefits of higher frequencies above 3 MHz, leaving the "worthless" frequencies to be experimented with by the amateur community. For those who continued experimenting with communications in general, they discovered the improvements in long-distance conversations when using higher frequencies, as well as the fact that antennas get shorter as frequencies go higher.

Exhibit III-1

Wireless Transmission in 1897

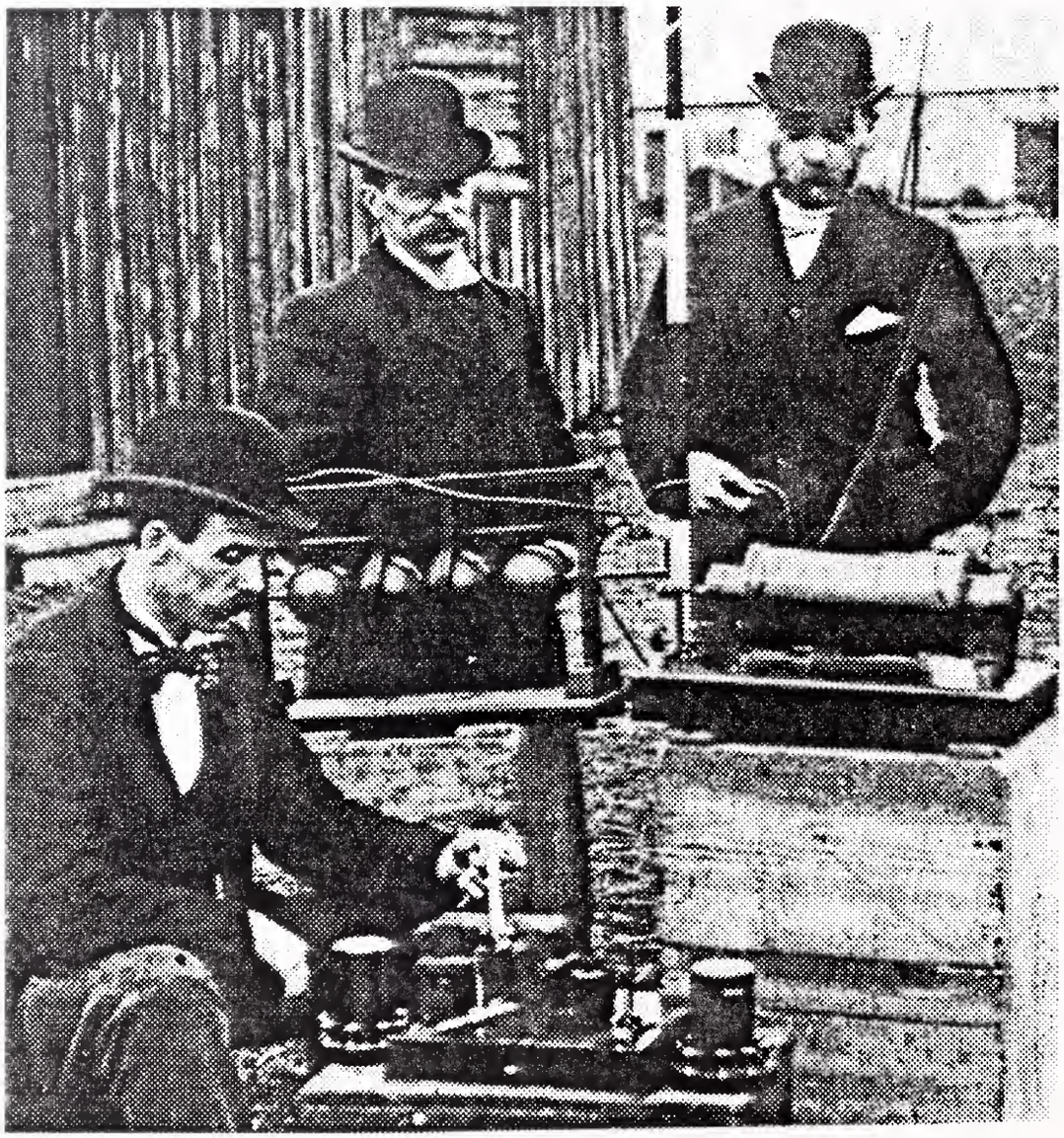
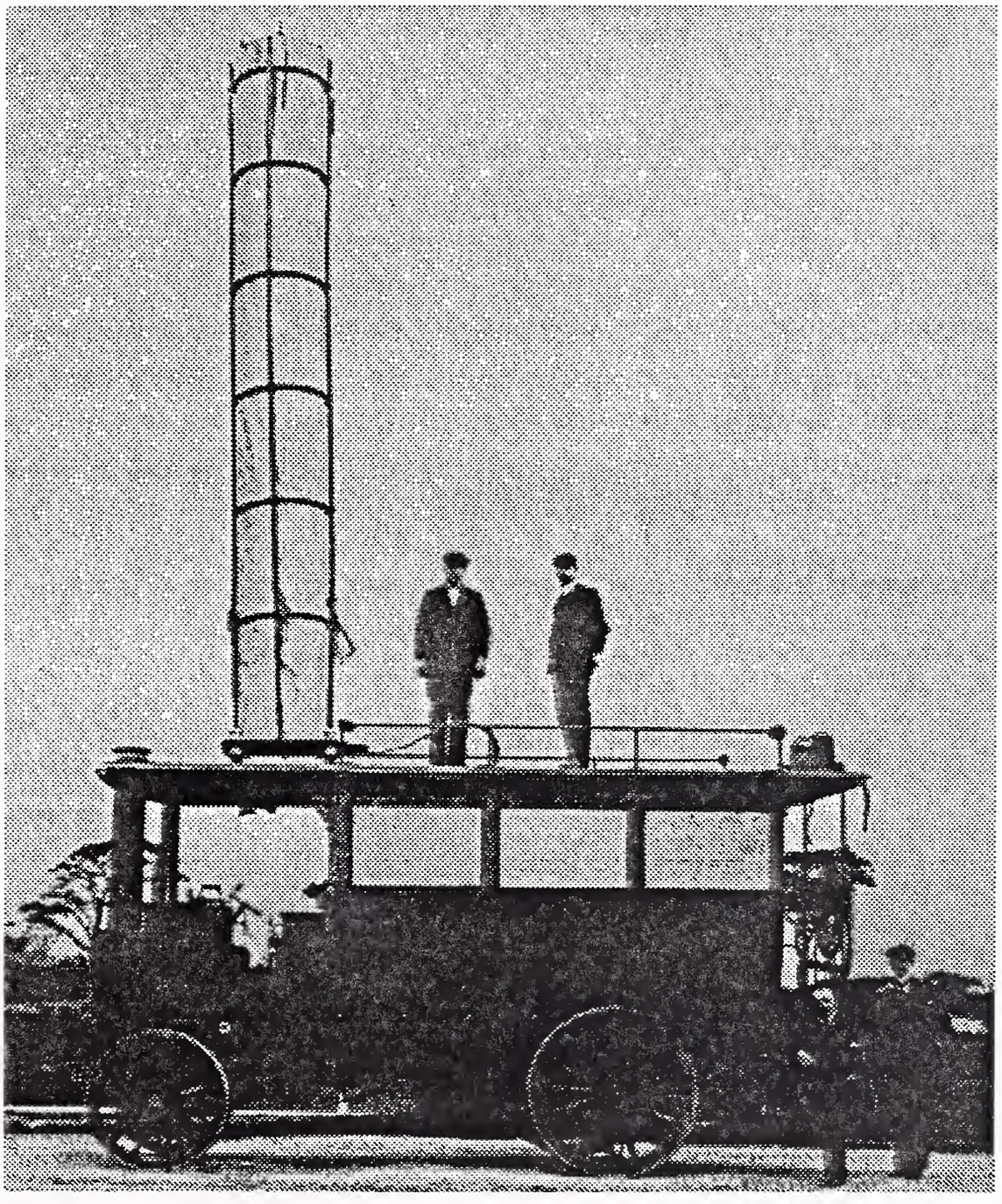


Exhibit III-2

Mobile Radio in 1901

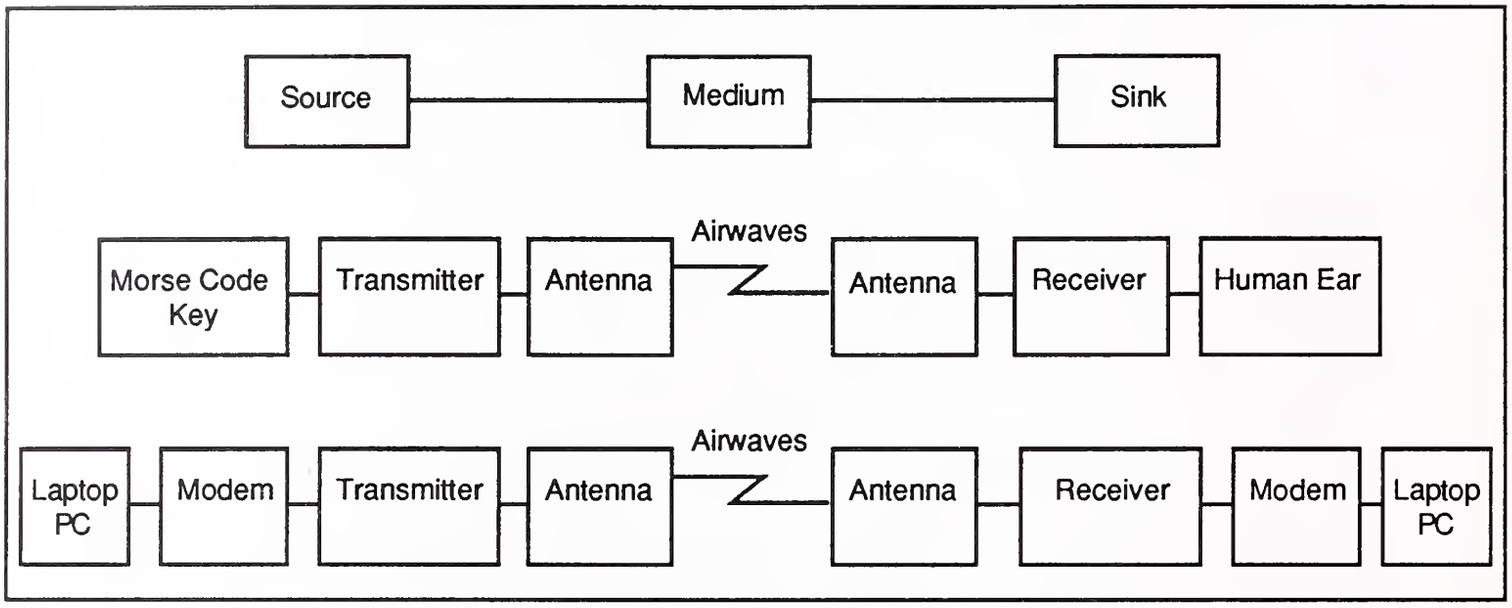


Forty years later, Webster's New International Dictionary defined the word 'wireless' as short for wireless telegraphy or telephony—chiefly a British term for radio transmission. If you were going to use this method of (relatively reliable for the time) telecommunications, you would still need a Morse Code key, a

transmitter and receiver, and a large, very tall antenna—not to mention a pretty good working knowledge of the International Morse Code.

Exhibit III-3

Components of Wireless Communications



While the traditional wireless telegraphy has declined in use, being perpetuated by amateur radio operators, international foreign services, and a few "clandestine operations," it still represents the "basics" for all of today's wireless systems. "Basics" in the sense of a transmitter, receiver, and a much smaller antenna, (thanks to 800 MHz operation). The Morse key has been replaced by a number of terminals such as the PC laptop and the PDA (personal digital assistant). The Morse Code has changed a bit, too, having been replaced with the much larger ASCII (American Standard Code for Information Interchange) code set. Dots and dashes were replaced with ones and zeros.

Today, the term 'wireless' has a significantly different meaning that is expected to change and enhance the ways we telecommunicate, primarily by replacing the dedicated hard-wired medium with radio waves. By cutting this “umbilical cord,” we are now free to perform other or concurrent tasks, away from the desk.

Until the late 1980s, radio communications had been a relatively staid marketplace; being regulated, primarily by the FCC (Federal

Communications Commission). The radio frequency spectrum (a finite commodity) was divided into categories, or "bands," to support multiple applications, including broadcast, government, public service, utilities, amateur, and several business categories. Those business categories included, among many applications, mobile telephone and paging services.

But the staid atmosphere began to change in the early 1980s with the introduction of cellular telephones. User demand in this industry is now growing at a remarkable 40% per year. This growth is attributable to a combination of aggressive marketing, continued reduction in size of cell phones, extended battery life of portable devices, advanced features such as roaming, and an increasing acceptance of this new medium. Essentially, we became more reachable and discovered another way to become more efficient.

B
Rapid Evolution

As previously noted, radio communications has been with us for a number of years, evolving through radio teletype to greater sophistication when it was integrated with computer technologies in the early 1960s. Only a few years prior, when the first radio version of an ethernet message system (Aloha Net) was implemented in Hawaii as an academic inter-island communications system.

Mobile digital, as it was called in the early 1980s, received a major push from law enforcement when it became an accepted component of the law enforcement vehicle. Amateur radio operators were also beginning to replace their vintage radio teletypes with a thing called packet radio. Another push came when PCs and laptops became available as inexpensive and portable ways to store and forward messages.

In late 1988, a milestone was crossed in telecommunications—the U.S. began to exchange more information by means of data transmission than by traditional voice telephony. Its significance is monumental as we continue forward at an ever-increasing rate into the digital world of ones and zeros (dots and dashes). The

wireless world is becoming an integral part of this digital evolution.

There are now over 10 different ways to send the traditional voice, data, image (fax), paging, and video information via wireless transmission. Many of these services are capable of sending more than one form of communication.

With new reasons to communicate, it now makes more sense to integrate voice, data, and paging into one device—via wireless.

- It is now possible to have a nurse or doctor carry a handheld wireless device as they make their rounds at the hospital or as they travel between offices (still no house calls).
- It is now possible to have an over-the-road truck driver use a mobile wireless device that tracks everything from estimated time of arrival, to load and dispatch data, to emergency messaging, to exact location of the vehicle.

IV

Concepts and Technology

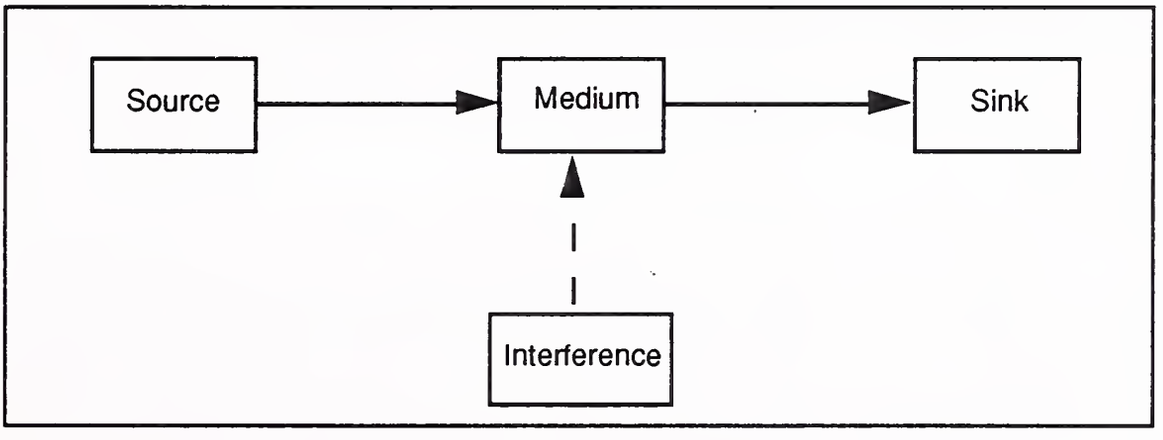
A
Conceptual Approach

What is required to extend our communications capabilities into the world of wireless? The intent of this review is to convey the conceptual components rather than an in-depth technical approach. Perhaps it may be helpful to keep in mind that all telecommunications systems are made up of three simple components:

- A source to generate information
- A medium to pass information
- A sink to receive information

Exhibit IV-1

Basic Communications Components



The three component analogy applies very well to wireless. Every wireless system will require a transmitter (source), some part of the radio frequency spectrum (medium) to pass the information, and a receiver (sink) to accept it.

A problem with any communications system is that sometimes an unwanted fourth component called interference is interjected into the medium. Unfortunately, wireless is considerably more prone to interference than most other media of today.

B
Transmission Configurations and System Components

For the purposes of this review, there are six essential configurations of radio systems. They are:

- Broadcast (uni-directional, one-way)
- Point-to-point (usually bi-directional, two-way)
- Multipoint (usually bi-directional)
- Repeated or repeater (uni- or bi-directional)
- Cellular (multiple interconnected repeaters— bi-directional)
- Micro-cellular (multiple interconnected repeaters - bi—directional)

Exhibit IV-2

Radio System Configurations

Configuration	Transmission Direction	Wireless System
Broadcast	Uni-Directional	TV/Radio Paging
Point-To-Point	Bi-Directional	Local two-Way Radio
Multipoint and Trunked Multipoint	Bi-Directional (usually)	Taxi/Truck Dispatch SMR and ESMR
Repeated (Active) Repeated (Passive)	Uni- or Bi-Directional	Taxi Disp. or Satellite Meteor Burst
Cellular	Bi-Directional	Cellular Telephone/ LAN and PBX
Micro-Cellular	Bi-Directional	PCS

1. Broadcast

Broadcast systems are the simplest in configuration and are comprised of a single transmitter, usually a multi- omni-directional antenna to cover a relatively large area. The size or circumference of that receiving area can vary from a few feet to several thousand miles and the system will be designed to fit the application. The receiving end is usually comprised of several "listeners," often physically located in different places.

2. Point-to-Point

These systems are more specific and require a transmitter/ receiver combination in two different locations. Sometimes these combinations are referred to as transceivers—physically mounted within the same box. Antenna systems for point-to-point systems are often designed to favor the specific direction of the other location. Again, the distance between the two systems can vary from a few feet to several thousand miles and they are designed to fit the application.

3. Multipoint

A multipoint configuration is necessary to support more than two "stations" communicating with a host location. This would be typical of a taxi dispatch application. The system uses a single base transceiver station with an omni-directional antenna. The other remote stations, can be a combination of fixed, mobile, or portable configurations—the mobile and portable systems would require omni-directional antennas. All stations must adhere to the verbal traffic directions (protocol) given by the base station to avoid chaos.

In a computer message switching environment, the exchange of information between stations is performed by a specific data traffic management protocol. Though there are numerous protocols, packet protocols such as X.25 work very well in this environment in much the same way as they do over an ethernet LAN. Carrier Sense Multiple Access/Collision Detection (CSMA/CD) takes on a very similar function as traffic cop, but over the air waves. If two radio stations try to talk at the same time, both go into a random retry algorithm before trying to transmit again, to avoid the inevitable "collisions." In today's systems, many receivers actually listen or "sense" for another

transmitter's "carrier" (a basic part of a radio transmission) before initiating a transmission. (Now you can tell your friends at the next cocktail party what CSMA/CD actually does.)

4. Repeated or Repeater Systems

Systems that require repeated, or repeater, stations usually have a moderate to large audience of remote stations that often are in more remote areas or located in areas that impede the passing of radio frequency signals. The "repeater" is a more powerful transmitter/receiver that operates simultaneously on two separate frequencies and is strategically located in a tall building or tower. It listens for any transmitted signal from any of its remote stations. When it receives a transmission from one of them, it simultaneously re-transmits (essentially re-broadcasts) the incoming signal so that the entire community of stations can hear what would otherwise not be heard.

Although there are a great number of repeaters that support anything from taxi companies to water utilities, repeaters are also the basis for satellite transmission—"echoing" whatever they hear on the received frequency and re-broadcasting it on another.

Sometimes it is desirable to have certain objects or things actually block or "reflect" a radio signal in another desired direction. It can be advantageous to "bounce" signals off of passive surfaces such as other buildings—a practice done extensively in metropolitan areas. Long-distance radio transmission uses the same theory, except that it takes advantage of another reflective surface called the ionosphere, located some 60 to 260 miles up from the earth's surface.

So what's this got to do with the bottom line of wireless, you ask? For several years, now, businesses have been using a very effective means of wireless transmission that is based on the passive reflective theory. It was discovered as a logical offshoot of amateur experimentation when signals were bounced off the northern lights. It was posed that meteorites also leave a charged trail of ions as they burn up in the earth's atmosphere. Given that the earth is being bombarded on a regular basis by these particles, wireless signals are squirted at the reflective surface that meteorites leave behind as they enter the atmosphere. This is a very real transmission mode called meteor burst and it is one of

the earliest entries into the wireless world. (Although, admittedly, it employs an extra-terrestrial medium.)

5. Cellular

In simplest terms, cellular systems are multiple, interconnected repeater sites. Today's systems can support a little over 400 channels of conversation through a given cellular location. As one travels between cell areas, a hand-off takes place, passing a conversation-in-progress off to the next adjacent cell. A cellular system is arranged in a honeycomb-like configuration. Given that there are a finite number of channels, a frequency re-use scheme is employed to effectively manage the use of multiple cell sites so that adjacent cell frequencies do not interfere with each other. Significant congestion in metropolitan areas is beginning to take its toll. Later in this report, ways to expand the capacities of these systems will be addressed, as will the impacts of the now familiar term, "digital."

6. Micro-Cellular (Personal Communications Services)

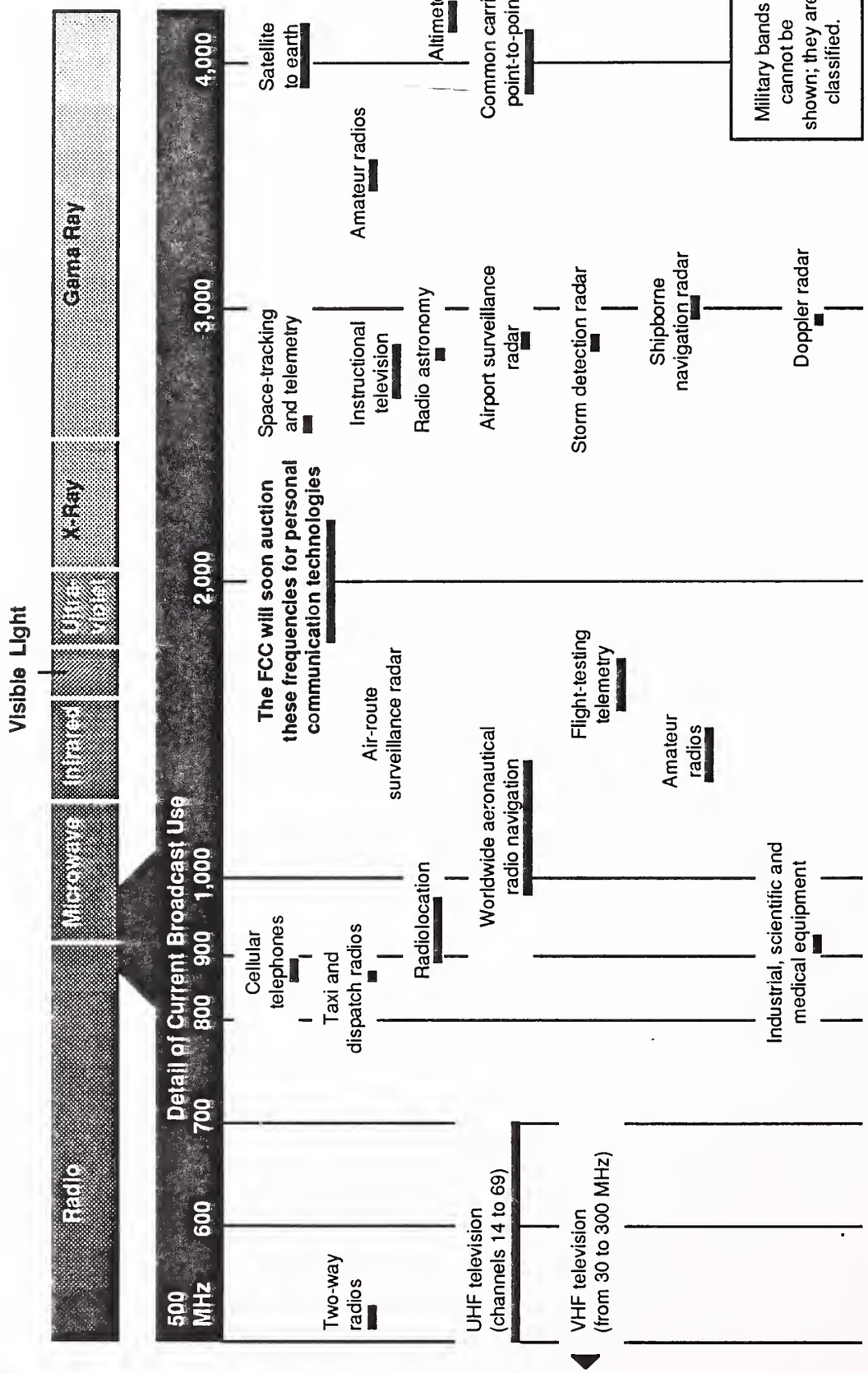
Micro-cellular systems are based on the same basic concepts as cellular systems, except that the cell groups cover a smaller range, requiring more cells to handle a given area. Aside from that, the differences are in the smaller size of the access device due to its lower power needs. Also, there is the potential to have a single telephone number assigned to you for mobile and office use. (Just think—you won't have that impressive list of telephone numbers that occupies a majority of the space on your business card.)

C
Radio Spectrum—A Finite Medium

The radio spectrum is a limited medium that is controlled by the Federal Communications Commission. Exhibit IV-3 shows how the FCC has allocated the portions of the frequency spectrum that are relevant to cellular, private packet Networks, and PCS (personal communications services).

Exhibit IV-3

Wireless Radio and Microwave Spectrum



Source: New York Times

Various transmission technologies have evolved over the years that attempt to conserve the amount of space (frequencies) required to hold a conversation. This conversation space is called a channel. It accepts an audio frequency range of 3,000 Hertz (3 KHz) and superimposes that audio conversation onto 30,000 Hz of radio frequency spectrum for transmission of a typical cellular call.

The point to be made is that we are starting to encroach on the limits of a fixed "commodity", which requires conservation. For example, if two transmitters are in the same town and activate at the same time on the same frequency, either one or both will be unable to effectively communicate due to interference. If we continue using what is called a wireline medium such as copper, television coax, or fiber optic cables, the conversations usually stay within the medium. Capacity problems are easily overcome by installing more cable in the same conduit.

There are some things that communications engineers have been working on that look promising when it comes to the conservation issue. When cellular telephone was first implemented, it was considered a fairly good design in economizing frequency. Those 400 channels are divided up amongst a cell area using a 1-in-7 algorithm. To avoid interference between adjacent cells, a cell can only use an allocation of one-seventh of all the available channel frequencies.

D
Digital Multiplexing —TDMA versus CDMA

The superimposing of multiple conversations, or multiplexing, continues to be used extensively throughout the telecommunications industry. This multiplexing technique is well under way in the radio industry, too, and dates back to the early 1940s. One way to recognize a maturing radio industry is to observe the amount of multiplexing projects under way. Cellular is now about 10 years old and is facing some significant capacity problems—especially in light of the 40% growth rate and the pending demand for data transmission services.

There are two digital multiplexing approaches in the cellular industry, both of which have their good and not-so-good points. It

certainly gives rise to questions of standards, similarly to the beta versus VHS video tape dilemma.

Several organizations are behind a standard called TDMA, or Time Division Multiple Access. It adheres to the current 30,000 Hertz (30 KHz) channel standard and subdivides it into three additional subchannels. However, at this time there doesn't seem to be a way to pass data through these new subchannels.

The primary alternative is CDMA, or Code Division Multiple Access. It was adopted by the Telecommunications Industries Associates (TIA) in 1993. CDMA uses what is called a wideband scheme that defines 64 different channels over a 1.25MHz (megaHertz) spectrum. The end result of this different approach works out to be about a 7- to 9-channel improvement over one of today's analog channels. It requires some tighter operational parameters, but it, too, does not take into account the need for data transmission.

Where TDMA uses what is called narrow band technology that operates on a specific frequency while it is in a given cell, CDMA uses a new wide band scheme that distributes a conversation over multiple channel frequencies (within a given cell). It anticipates collisions with other conversations and has ways to avoid this potential interference. It is rendered considerably more efficient by using this available frequency hopping method and will be discussed in more detail in other parts of this report. The end result of this digital technology works out to be upwards of a 20-channel improvement over current analog channels.

E
Cellular Digital Packet Data—CDPD

Given that current methods of data transmission over the cellular analog system leave much to be desired, the cellular industry plans to deploy a new, more robust data transmission technology called CDPD, or Cellular Digital Packet Data. It has been developed by a consortium of eight Cellular operators and will be implemented over the next two to three years. However, it may be years before seamless roaming is possible and until billing issues are resolved between carrier regions. When compared to PPNs (private packet networks), CDPD should be cheaper, faster, and offer considerably greater coverage. Its installation can be described as an overlay or piggyback over the current cellular network. Data transmission speeds are expected to increase to 19.2 Kbps, or twice the speed of the current analog architecture. CDPD also takes care of security issues through a network interface device that encrypts data as part of the overall transmission process.

F
Wireless Systems

The following discussions will review the various types of wireless products and services. As previously noted, there are over 10 different ways to send wireless information. Exhibit IV-4 reviews rollout and service offerings by system type.

Exhibit IV-4

Wireless Rollout and Services

Wireless System	Rollout Activation	Modes of Communication	Geographic Coverage (U.S.)
Cellular - Analog	Active	Voice/Data/Fax Limited Page	95%
Enhanced Cellular Digital - TDMA/CDMA	Under way	Voice/Page	95% Eventually
Enhanced Cellular Digital - CDPD	2 to 3 Years	Data/Fax	95% Eventually
SMR	Active	Voice	95%
Enhanced SMR	Under way 1 to 2 Year Completion	Voice/Page/Data Fax	95% Eventually
PCS	2 to 3 Years	Voice/Page/Data Fax	Major Metro Areas
PPN	Active	Data/Fax	Metro Areas Only
Paging	Active	Page/Alpha-Page	95%
Enhanced Paging	1 to 2 Years	Two-way Page/Alpha	Metro Areas First
Satellite	Active	Voice/Page/Data Fax	100%
Satellite LEO	2 or More Years	Voice/Page/Data Fax	100% + Int'l
LAN	Active	Data/Fax	Local Area
PBX	Later This Year	Voice/Page/Fax	Local Area

1. Cellular Telephone

Cellular systems have been evolving for 10 years, and provide predominantly voice and some data capabilities through mobile and portable wireless devices to their 13 million users. The conversion to digital technology is just beginning and enables the

offering of more data services, including enhanced paging. Services are distributed across the U.S. in metropolitan and regional installations (including primary transportation corridors) that support the greatest potential for portable telephone traffic. Cellular systems are usually marketed on a duopoly concept (except in major metropolitan areas) and rely on telephone (wireline) and non-wireline companies. Wireline companies include RBOCs like Ameritech and US West; non-wireline includes companies McCaw Cellular. Cellular is based on the AMPS (Advanced Mobile Phone Service) narrow band FM system design, is limited to three watts of transmitter power, operates over several frequency portions of the 800 MHz band, using a total of 50 MHz, and is specifically partitioned to support the two separate entities.

2. Specialized Mobile Radio/Enhanced Specialized Mobile Radio (SMR/ESMR)

Specialized mobile radio got its start in the taxi cab and trucking dispatch industries. It is sometimes still referred to as '"runked radio" because of its method of interconnecting radio repeater sites. In 1993, the FCC authorized the expanded use of this area, using a newly developed digital technology created by Motorola. Motorola sold off over 2,000 operating licenses in this area to three companies, but retained a limited financial participation with all players. The three companies are Nextel Communications (the most visible), CenCall (now OneComm), and Dial Page. They represent the beginnings of another nationwide wireless network. Other major investors include MCI, Comcast, and NTT. Enhanced SMR, as it is now called, has begun its rollout in the Los Angeles area and is targeting commercial markets. The new transmission technology developed by Motorola enables ESMR service to offer voice, paging, and data (planned for later this year) through one mobile handset, developed by Motorola on a proprietary basis. Its current power requirements are between 12 and 25 watts, with frequency allocation limited to portions of the 450 MHz and 800 MHz bands. Even with the new digital transmission techniques, it will need more frequency spectrum to meet growth projections. The group, including Nextel, is expected to be one of the bidders in the upcoming FCC auction for a portion of the 160 MHz set aside for the new personal communications services in the 2 GHz (gigaHertz) band. SMR

has about 1.5 million users today, and its revenues represent less than 5% of all wireless revenues.

3. Personal Communications Services (PCS)

The FCC has given this wireless service a very broad definition of services and devices addressing voice, data, image, and video. Though PCS has not yet been implemented, its planned method of transmission is very similar to that of cellular telephone concepts. However, because PCS is based on a subwatt (milliwatt) power concept, it will require many more cellular repeaters in a given (very likely a metropolitan) area than current cellular technology. One of the expected benefits is a lighter telephone handset because it requires less power and a smaller battery to get to a cellular repeater site—perhaps one cell site every few hundred feet mounted at the top of a telephone pole. (And yes, utility companies would also like to participate in parts of this industry.) Another benefit is a single telephone number that is assigned to a person as opposed to a place.

The potential players in the PCS marketplace include just about everyone—RBOCs, local exchange carriers like GTE, long-distance companies, cable TV companies, and a few start-up organizations. A multitude of issues remains to be ironed out, which may explain why MCI dropped their PCS consortium plans in favor of buying into ESMR through Nextel. For example, one of the key issues is to ensure that cellular operators do not develop and operate PCS business in their own cellular territory. Also, the PCS frequency assignment and auction issues, currently under study, concern some very significant issues, which are covered in Chapter V.

4. Private Packet (Radio) Networks (PPN)

There are two primary players in the PPN arena. The first is Ardis, a joint venture of IBM and Motorola which was developed to support IBM field and customer engineers as they made their rounds to customer sites. The portable terminal allowed dispatch, parts availability, and general messaging information. The other PPN is called RAM Mobile Data, and is comprised of RAM Broadcasting and the RBOC Bellsouth; it uses the Mobitex technology developed by Ericsson. Both offer two-way data communications and E-mail messaging through a number of handheld and portable devices. Much of the focus in these

networks is in metropolitan areas. Ardis accounts for the majority of users, approximately 34,000. RAM has about 3,000 users.

5. Paging, Enhanced Paging Service (EPS) and Broadcast TV and Radio

The paging industry can be considered a relatively mature industry in that it has been around for a number of years and offers cheap and reliable one-way service. Paging devices are now a commodity item (even with alpha-numeric messaging); market differentiation is determined by price and geographic coverage. Enhanced paging takes this process into the realm of two-way activity, allowing users to respond with a positive receipt of message acknowledgement. Though this receipt messaging was done approximately 10 years ago, its chance for success is enhanced by continued growth in commercial applications and expansion into personal use. Players include the RBOCs, SkyTel (MTel), PageNet, and EMBARC (Motorola). Another recently announced player is a consortium called Nationwide Wireless Network (NWN) and is comprised of Microsoft and MTel (Mobile Telecommunications Technologies Corp.)

Broadcast television and radio support paging by sharing a small portion of their transmitted bandwidth with paging companies. By interconnecting these systems with a combination of traditional telephone and satellite links, these broadcast transmitters provide considerable expansion into markets that would otherwise not be profitable. These networks enable the paging company to offer nationwide service at favorable rates.

6. Satellite and Low Earth Orbit (LEO)

Although satellites offer much greater geographic coverage potential over terrestrial-based repeater and cellular systems, they are very costly to deploy and require long-term capitalization as users come on board. A long-distance cellular call including roaming charges might run a little over a dollar a minute whereas a satellite call could be as high as three dollars a minute. Obviously, the need for ubiquitous communications in more remote areas will continue to drive this market.

However, it is possible to lease a portion of a satellite, thus sharing the risk and reducing the cost of operation. QUALCOMM uses a

segment of the 12-14 GHz (Ku-band) Fixed Satellite Services to support its two-way mobile communications system. It has very good success providing dispatch, messaging, and location reporting for the long-haul trucking industry.

Significant LEO projects have been proposed by consortiums made up of major players. The first, Iridium, is comprised of Motorola, Sprint, and Sony. The other more recently announced LEO, called Teledesic, is made up of McCaw Cellular, Kinship Partners, and Microsoft. Others include QUALCOMM, which plans to participate with a service called Globalstar. All of the LEO projects are considered high risk and very expensive because they require multiple satellites to be deployed and require the usage and acceptance by all countries of the same frequencies.

7. Local-Area Networks (LANs) and Wireless

Wireless LAN data rates vary from 19.2 Kbps to 20 Mbps, with effective transmission distances of up to about 800 feet. Most LAN transmitters are not required to be licensed by the FCC because they operate in the Industrial, Scientific, Medical (ISM) bands, using frequencies in the 902 to 928 MHz band, the 2.4 to 2.484 GHz band, and the 5.765 to the 5.850 GHz bands. Some of them operate in the infrared frequency ranges, although these signals cannot pass without direct line of sight. The systems operate using very low power and several different transmission technologies, including spread spectrum and narrow band. Wireless LAN systems are available from over 20 vendors.

8. Private Branch Exchanges (PBXs) and Wireless

PBX vendors are approaching wireless with at least two primary offerings. The first is a "local" system that operates strictly within the confines of a given PBX installation. It is based on the unlicensed area of PCS frequencies in the 1.9 GHz area and uses very light-weight, long-term battery life, telephone handsets. The radio system operates with individual cell areas supporting a pre-defined, maximum number of callers. Cell sites operate from strategically placed "repeaters" in optimum coverage locations such as hallways. The handsets have all the features of a typical home telephone, plus all the extra features of a PBX and optional voice mail capabilities. These systems operate in the unlicensed portion of the PCS band.

The second system is designed to integrate cellular telephone (820 to 890 MHz) into the PBX on a wireless basis. The benefits would be a portable telephone that works at the office as well as in any other cellular area in the country. However, its financial implications are like any other cellular system, with additional costs for wide-area air time and monthly service fees.

9. Meteor Burst

Using the passive reflector approach, radio signals are bounced off meteor trails to exchange two-way messages. It is a less expensive way to communicate across all parts of the country without the aid of satellites and earth stations. As previously noted, it might take several minutes before the data reaches its destination. However, it is a very reliable method of transmission over medium to long distances.

10. Other Private/Public Radio Systems

There are several other private radio systems, many of which have been the mainstay of business and government for many years. These applications range from systems like GMRS (General Mobile Radio Service) to the mobile air telephones in commercial airplanes.

G
Wireless Terminals

Apart from the traditional cellular telephone, there are several different types of wireless data terminals, including some that have voice capabilities (see Exhibit IV-5). Mobile computers are largely the result of design compromises due to packaging, computing technologies, and limited battery life. As a result of these compromises, and given the breadth of numerous applications, it is not surprising that the process of evolution has delivered several different species. The categories of mobile computers include:

- Enhanced Paging Devices
- Subnotebook Laptops
- Hybrid Pen Notebook Laptop Computers

- Personal Organizers, Palmtops, and Specific Application PCs
- Personal Communicators
- Personal Digital Assistants

Exhibit IV-5

Types of Wireless Terminals

Type of Wireless Terminal	Type of Wireless Service
Enhanced Paging Device	Paging Services
Subnotebook Laptop	Cellular/ESMR/PCS/PPN/Satellite/LAN
Hybrid Pen Notebook Laptop Computer	Cellular/ESMR/PCS/PPN/Satellite/LAN
Palmtop and Specific Application PCs	Cellular/ESMR/PCS/PPN/Satellite/LAN
Personal Communicator	Cellular/ESMR/PCS/PPN/Satellite/LAN
Personal Digital Assistant	Cellular/ESMR/PCS/PPN/Satellite/LAN

1. Enhanced Paging Devices

The precursor to mobile computing and wireless applications was, and still is, the paging device. The introduction of the vibrating alarm and alpha-numeric display was a great improvement over its predecessor, which suffered from the occasional outburst of loud beeping tones followed by an unintelligible audio message. The new alpha display device is light weight, has extended battery life, and can do even more than display a telephone number. It can receive multiple, limited-character E-mail messages, which can be displayed, stored, and recalled at will. Also, rollout for acknowledged receipt of message (2-way paging) should occur this year. Pagers have become a commodity costing less than $100 and can be purchased from numerous vendors.

2. Subnotebook Laptops

The devices have become one of the primary mobile computing devices because they are so similar to the traditional PC and laptop. Given this software and computing design commonality, it has become a logical choice for on the road communications.

3. Hybrid Pen Notebook Laptop Computers

Certain applications, like those needed by insurance adjusters, have driven the development of pen-based systems which, until recently, used the pen-based interface to identify various parts of automobiles. Some of these systems now include an optional keyboard.

4. Palmtops and Specific Application Palmtop

Palmtop computers perform all the functions of a personal organizer, reflecting the need for a very small computing device. Though sacrificing capability for adjustment in size, they provide personal calendaring, note taking, and calculator functions. The palmtop takes personal organization a step closer to the traditional PC by using a DOS operating system and a communications interface that can interface to E-mail.

The specific application palmtop is usually configured for a specific task such as language translation or encyclopedia information, or is reprogrammed to send faxes. Some may eventually have the option of adding alpha-numeric paging.

5. Personal Communicators

These devices couple pen computing and fax transmission with voice cellular telephone capabilities. Devices that include proprietary microprocessor operating systems include AT&T's Eo and BellSouth's Simon. As Microsoft and Compaq introduce their "Mobile Companion", the other participants in this market area may want to consider the possibilities of Windows compatibility. Having the ability to run Windows software and to communicate through data, fax, or voice media should be of significant interest.

6. Personal Digital Assistants

PDAs are more sophisticated than personal communicators because they include the computing power of a PC, but rely on pen-based entry. Devices include Apple's Newton MessagePad and Tandy's Zoomer Z-PDA. The Newton attempts handwriting recognition, while the Z-PDA relies on block-print recognition. Both devices are very versatile in information management, can support one-way messaging, and are expected to be able to perform two-way messaging later this year.

Another PDA just brought to market is the Motorola Envoy. It has built-in communications capabilities, including a place for two PCMCIA interfaces and multiple ready-to-use E-mail packages. The Envoy's applications are based on General Magic's Magic Cap operating platform and its Telescript language, which allows the device to interact with multiple hosts and services.

7. Batteries and Standards

The addition of nickel-hydride batteries (replacing nickel-cadmium) and the PCMCIA standard interface (Personal Computer Memory Card International Association) have made some significant changes to mobile computers. The results are longer battery life and the ability to quickly expand or reconfigure devices.

H
Software and Integration

The software supporting wireless applications has expanded far beyond dumb terminal emulation, having now evolved into three separate areas:

- User
- Middleware
- Services

1. User

Software supporting this area tends to address the remote control of wireless connections into various applications. Companies that promote this type of software include Microcom's Carbon Copy and Norton's PCanywhere. E-mail vendors such as Microsoft Mail and cc:Mail Mobile also provide a wireless version to accommodate the longer time out windows, necessary in setting up connections over radio systems. In addition, there are remote LAN packages such as Apple's AppleTalk Remote Access and NCR's WaveLAN that extend the LAN's connection to the mobile computer.

2. Middleware

This area supports developers who needs a way to create their own wireless interfaces and application. It can interface to private packet networks like RAM and Ardis, or Cellular's CDPD. Nettech Systems' RFmlib and Radiomail's Radiomail API are two products that offer an API (applications program interface) to simplify the communications interface, relieving the developer to focus on the application. Also, General Magic's Telescript and Magic Cap are planned to provide middleware as well as a user interface.

3. Services

These services provide wireless messaging services with gateways to Compuserve, AppleLink, and Internet. Vendors include AT&T's Personalink (for personal communicators) and Radiomail Corporation's Radiomail product which operates through the RAM and Ardis networks.

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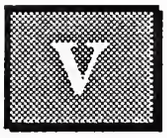


Wireless Marketplace

A
Regulatory Environment

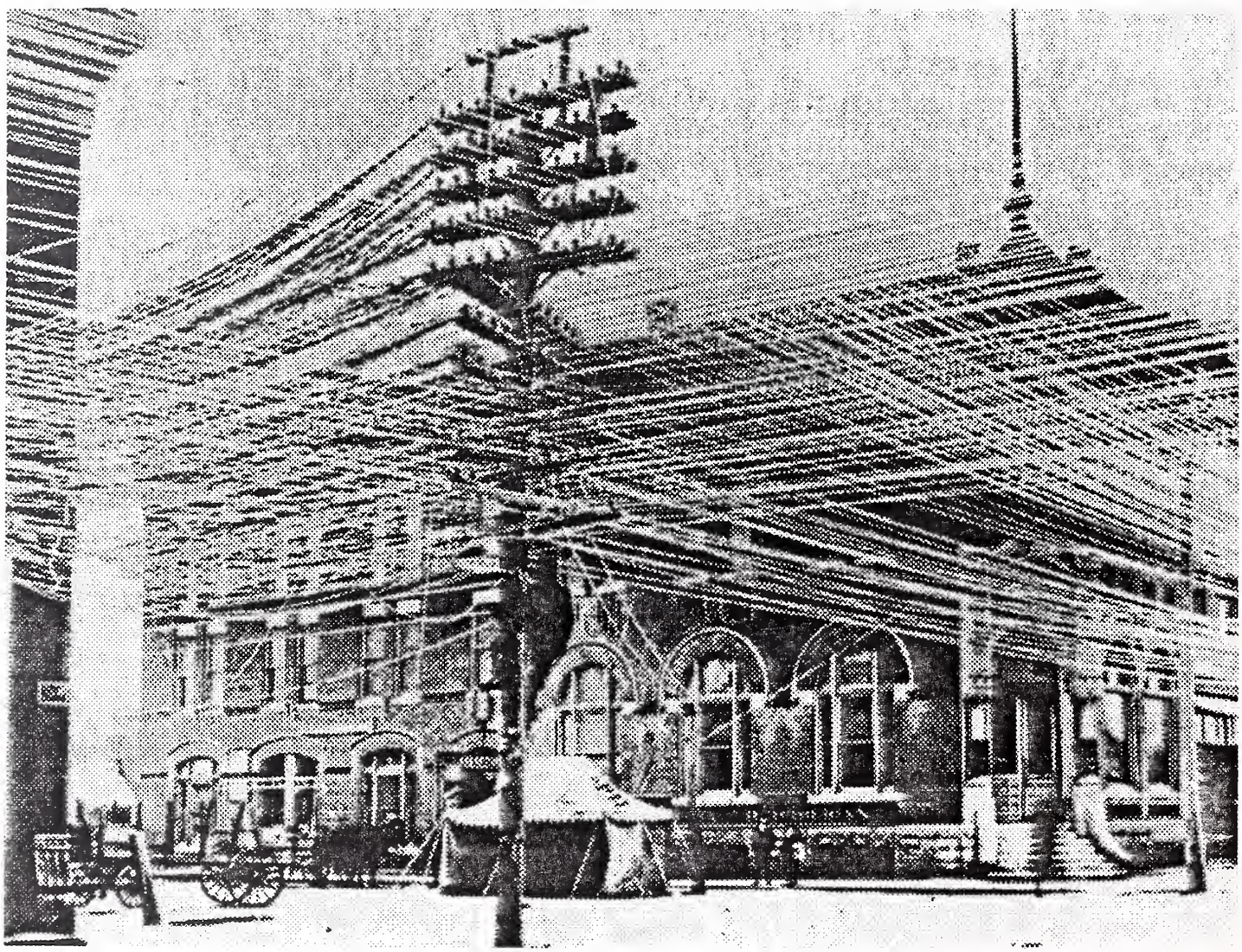
1. Congressional Rewrite of the 1934 Communications Act

A major effort is under way to rewrite the antiquated Communications Act of 1934, which was written when technology limits were set by the number of telephone lines that could be strung (see Exhibit V-1). The legislation seeks to make significant changes to the long-regulated telecommunications industry by reducing regulation and opening markets to competition on several fronts. These pending decisions are the result of rapidly changing technologies, changes in the way the U.S. and the world conducts business, and understanding that free markets work better than regulated ones when it comes to holding costs down and keeping productivity up. All these decisions come at a time when the U.S. government is under extreme pressure to reduce a huge national debt and reverse trade deficits with other countries.

The telecommunication industry's annual revenues exceed $300 billion. As an industry, these revenues are growing at about 8% per year. But some of the areas affected by this legislation are growing at up to 40% per year. Ultimately, hundreds of millions of dollars will be spent on new ways of communicating more effectively.

Exhibit V-1

NY Telephone Poles, 1909



Lobbying efforts over the past six months have increased significantly as telephone, cable, broadcast, and wireless industries plead their cases for a better position on the so-called information highway.

2. Rewrite Events and Issues

What is behind all the turmoil? A high-level view of the situation reveals that:

- Long-distance companies pay local exchange carriers (LECs) and Regional Bell Operating Companies (RBOCs) about 45 cents for every dollar of long-distance revenue.

- Long-distance companies want to bypass the LECs and go straight to the user's doorstep. With a bypass system in place, the long-distance company can offer incentives to the user of, say, a 20% discount below current prices, creating a win/win situation for the vendor and the users.

- RBOCs get about 40% of their revenue from these fees—and do not plan to stand still while the corporate coffers are drained.

- The RBOCs are in the process of being deregulated. When the Bell System was broken up in the early 1980s, the seven RBOCs were formed and were explicitly forbidden by federal decree to participate in three areas:

  - Content-based information services
  - Manufacturing
  - Long distance

  RBOCs have been allowed to offer information services for the past two years.

- The RBOCs' best chance for continued prosperity is in the offering of long-distance services and manufacturing. The latest amendment to the bills proceeding through Congress allows them to offer these services, just one year after the bill goes into effect. (Prior to this amendment, the bills had indicated a waiting period of five years.) The catch is that all other potential competitors will be able to compete in any of these markets as well.

- A major issue is the creation of a fair playing field for all vendors, prior to deregulation. That field would balance the "unfair" advantage of the LECs and RBOCs, of already having a hardwired link to every potential customer. Given this less "hostile" environment, there is belief that a certain amount of deregulation can work. The good news is that the FCC and the judicial branch have had some practice at this with the breakup of AT&T. But it is still a very challenging task. The bills have been placed on a "fast track," have the general support of the White House, and are slated for enactment by mid-1994.

B
Regulation versus Free Market

1. Allocation of Frequency Spectrum

The FCC envisions that the PCS area will carry a large part of the wireless requirement. The process of auctioning licenses by the FCC may be regaining momentum and could occur in the latter half of 1994. It is expected to generate $7 billion or more in revenue to the FCC/U.S. Treasury. Some of these monies will go toward the reassignment of the common carrier, public safety, and video microwave entities that will require alternative frequencies to continue operation.

The PCS spectrum is more than three times the size of the cellular services. The new spectrum has been divided several ways to support almost 3,000 new licensable markets—some of which are in conflict and are part of the current review process. The FCC is studying a work-around alternative that scales back its current commitment to smaller entities while mitigating FCC exposure to the inevitable court challenges. As a result, current frequency allocations may be subject to further adjustment. Currently, of the 160 MHz of spectrum allocated between 1.8 and 2.2 GHz, 40 MHz has been set aside for unlicensed operation of wireless systems supporting PBXs and LANs. The remaining 120 MHz is to be licensed for PCS mobile service.

2. Spread Spectrum Implications

One of the issues with which the FCC is grappling is the regulatory implications of a relatively new technology called spread spectrum. As previously described, it is an extremely efficient method of transmission due to its ability to be frequency-agile and hop between a number of frequencies during a "conversation," all the time avoiding collisions with other conversations, and operating at very low power. This is far more efficient than most of the dedicated narrow band radio systems of today. The problem for the FCC is to determine a workable licensing method that best supports the inevitable transition to this technology before making the auction commitment. Once a set of frequencies is auctioned off, it becomes the "property" of the new owner, represents a billion-dollar transaction, and has a 10-year commitment. With a commitment like that, it is unlikely that new owners would be willing to part with their frequencies. Or, later on, they may be told by the FCC that other companies will be traipsing across their investments on a regular basis.

C
Convergence Implications

1. Local Access Implications

The wireless industry sees the enactment of this legislation as a very important opportunity. Because the legislation encourages local bypass, this provides a new impetus for the cellular and PCS industries (as well as cable TV operators) to connect directly to long-distance carriers. Obviously, cellular prices will have to come down, but that is very likely, with the advent of PCS. This won't happen overnight, as it will take about a year and a half to two years before PCS can gain enough of a foothold to pressure the cellular industry to lower prices. This is also why the FCC has some doubt about awarding major PCS licenses to companies that already have substantial holdings in the cellular marketplace. The plan is to avoid a situation of "you can't have one if you've got the other." But the FCC will surely place operating restrictions on companies that already participate in the cellular industry.

2. Players and Motivations

Virtually everyone in the telecommunications industry wants a piece of the PCS auction, but demand will clearly exceed supply. Exhibit V-2 shows the categories of potential PCS players. Certain industry analysts used to think that there was an implied alliance between the RBOCs and the cellular industry, presenting the potential for cable TV concerns to link themselves with a PCS solution for local dial tone. After the false start of well-publicized alliances between Bell Atlantic/TCI and US West/Time Warner, the lines on the playing field have suffered great obfuscation. INPUT thinks that there are currently too many variables to support this tidy rationale.

Exhibit V-2

Potential PCS Players

- Local Exchange Carriers (RBOCs)
- Cellular Companies
- PCS Startups
- Long-Distance Companies
- ESMR Organizations
- Cable Television Companies
- Competitive Access Providers
- Mobile Satellite Vendors

- The long-distance carriers very much want strong PCS presence. Even though AT&T and Sprint have substantial commitments to the cellular industry, they (and MCI) will aggressively pursue PCS for the financial benefits of bypassing the local carriers.

- MCI has committed to the ESMR organization in a big way by making significant investments in Nextel, the most visible of the three primary ESMR companies. Until the end of 1993, MCI was the focal point of a 150-company consortium working to bring PCS on-line. Comcast, a cable TV concern, convinced MCI to scrap its PCS plans in favor of getting into the ESMR business. (ESMR rollout is happening, today, while PCS is at least two years off.) But MCI still plans to participate in the PCS auction because it knows that the current ESMR frequencies are too limited to support the envisioned traffic load.

- Sprint's abandoned announcement to merge with EDS could have lightened Sprint's debt load and allowed a more vigorous pursuit of the PCS industry. Sprint's ownership of Contel and its successful cellular business makes it no less a player in PCS than does AT&T's planned acquisition of McCaw Communications, the nationwide cellular concern.

- Another potential participant, as previously noted, would be the cable TV industry. Although, cable providers already have 58 million subscribers directly connected to their systems, there are a number of technological areas to be addressed before they can participate in the telephone services arena. Motorola has come up with a low-cost system for expanding the capabilities of these TV coaxial cables to support video, telephone, data, *and* wireless. The fact that it can transport both hard-wired and wireless connections is of significant interest to companies like Time Warner.

- Competitive access providers (CAPs) can also provide the interconnecting component for PCS. MFS (Metropolitan Fiber Service) Communications has decided to compete in one of the first convergence test-bed trials in Rochester, NY. The CAPs will compete with Rochester Telephone Company and Time Warner in providing telephone services. This telephone competition has the initial blessing of the New York PUC and allows competitors to connect their lines to customers through Rochester Telephone.

- Mobile satellite vendors would also like to participate in PCS activities. This would allow for expanded coverage into non-metropolitan areas. PCS users in Europe who already have their systems in place have been requesting this type of expanded coverage.

- Lastly, the power utilities would like to have a crack at the telecommunications industry. They have been operating microwave links stringing fiber optic cables along their rights-of-way to support their own internal networks. This network offers another bypass path and the potential to provide the interconnecting component of PCS systems. The second component, transmission, offers even greater potential when one realizes that thousands of PCS cell sites could be mounted on top of utility power poles. (See Chapter VI A.2.., "Technology Issues.")

D
Standards

Standards are a significant issue in any emerging and fast-paced industry. There is always need for standards—even de facto standards—to hold the product and service evolution together. Here are some of the more significant ones, keeping in mind that FCC frequency assignments and the upcoming PCS auction are among the most significant in the wireless industry.

One of the largest standards issues has to do with how cellular carriers plan to maximize their channel capacity through digital multiplexers . The standards are TDMA and CDMA, which were previously discussed in Chapter IV. Neither one of these standards can talk to the other, although handset manufacturers have been able to integrate the two standards.

Many international cellular carriers use different operations standards than the U.S.

The Unlicensed PCS Ad Hoc Committee for 2 GHz Microwave Transition and Management (UTAM) is responsible for clearing the existing frequency spectrum and relocating the incumbents.

The Telecommunications Industries Association (TIA) has a digital subcommittee (TR45.3) that is working with modem manufacturers in assembling standards for cellular transmission of asynchronous data, Group 3 fax, and short message services. Cellular providers such as Bell Atlantic's Airbridge service also help in this area by automatically translating between the V.xx and V.xxbis series and MNP 10 modem protocols, among others.

E
Market Drivers and Inhibitors

There are a number of market drivers and inhibitors that influence the wireless marketplace (see Exhibit V-3). What is somewhat unusual is that some of these points appear in both categories and have antithetical perspectives.

1. Drivers

a. Demand for Ubiquitous Communications

Demand for ubiquitous communications is providing a significant push to the evolution of the wireless marketplace. Users are considering the benefits of mobile computing to existing applications that, until now, could not be performed in the field. And they are observing the benefits of new applications that, until now, have never been automated. The barrier of fixed, non-movable computing is falling, and with it, the cost of operations.

These new and revised applications are not limited to the office environment and are occurring in all industries, including transportation, health care, manufacturing, hospitality, financial, retail, and utilities.

As users quickly learned the benefits of having easy access to telephones provided by the cellular industry, it is becoming equally evident that mobile access to computing represents another significant improvement in ways to best use time. Mobile computing helps users become more effective by accomplishing tasks any place and any time.

b. Competitive Business Climate

There is continuing demand in the business community to become more competitive; to drive up efficiencies while forcing down cost—and always, these activities are performed in the best interest of the customer. As a result of these new technologies, customers and computer users see shorter transaction times.

A computer user can now be the person who drives the forklift in a manufacturing plant, using a bar code detection device to quickly identify stock for shipment; a customer service representative at a car rental check-in area who meets customers as they return their cars for expeditious check-in and invoicing; or a truck driver who must alert the dispatcher to a breakdown in a remote part of the country and the need for help in servicing the vehicle.

Vendors must gain market share rapidly to obtain a foothold in the wireless business. Many wireless carriers offer similar, poorly differentiated services, with geography no longer a protective factor.

c. Fast-Paced Micro-Technology Evolution

Both wireless vendors and users are on a fast track. All of them need to keep up for different reasons.

The vendor has a computer usability life of about nine months before another technological improvement makes the device outdated. If the device falls behind in the development cycle, it is very likely that it will lose a significant percentage of revenue due to ever-increasing changes in technology.

Users need to stay on track with this fast-paced technology cycle to keep up with, or leap-frog, the competition. Obviously, user commitments to a given technology are financially challenged with even a three-year change in technology cycle. Vendors that recognize this challenge and provide a form of "evergreen" upgrading will receive positive consideration from users.

d. Major Investments by Large Players

Many large players in the telecommunications business are making substantial investments in wireless. Essentially, they are betting that their technology can be brought to market ahead of the

other players'. Large players bring name recognition, respectability and, in some cases, new technologies to parts of an industry that have been hanging back in the closet for a number of years. Past performance notes that typical growth was much closer to 3% to 5% before improvements in computing, device size, and demand for information began to rise. Some of the larger players include Motorola, Ericsson, GE, the RBOCs and GTE, long-distance companies, cable TV companies, and computing and software organizations including Apple, IBM, and Microsoft.

Exhibit V-3

Wireless Market Drivers

- Demand for Ubiquitous Communications
- Competitive Business Climate
- Fast-Paced Technological Evolution
- Major Investments by Large Players

2. Inhibitors

a. Unfavorable Regulation

If a company's technology is perceived by regulators and the marketplace as being less viable, it stands a chance of being cast by the wayside. There will always be a need for frequency coordination to regulate how and when those much-sought-after frequencies shall be used. Along the way there is a chance for considerable lobbying, which adds further potential to the sidetracking of potential vendor applications.

A good example of "best laid plans" occurred in 1988/89 when United Parcel Service (UPS) decided to go after a portion of the amateur radio frequencies in the 220 to 222 MHz band for its wireless applications. At first, things went well for UPS as it successfully argued that the band was never totally committed to the amateur community and was relatively underutilized by the current users. The FCC agreed with the UPS position and removed those frequencies from the amateur community. But then, several hundred other concerns heard of those frequencies and petitioned the FCC for their considerations. Subsequently, UPS abandoned any hope of using the 220 to 222 MHz band; the matter has languished in the courts ever since the arrival of all

the other petitions. (Hence, another good reason for the use of auctions.)

b. Lack of Radio Spectrum

The radio spectrum, being a finite commodity, has almost always been an impediment to the wireless industry. If a desired set of frequencies was not available, it meant prolonged hearings and court challenges. Also, many of these frequency allocations have international ramifications. A very good argument can be made to allocate the same set of frequencies throughout the world when it comes to satellites such as the LEOs, for example, or cellular and PCS phones, or shortwave broadcasting.

c. Lack of Standards

Again, this issue is a two-edged sword. There must be standards to create a common base to work from, such as everyone agreeing to use a particular cellular digital multiplex standard. With common standards, such as the IBM/Microsoft de facto standards for personal computers, many more vendors may become involved in an industry, resulting in huge market expansion. When there is a common standard, users run fewer risks of investing in obsolete technologies.

The other side of the conundrum is that these standards tend to retard real technological breakthroughs. For example, if broadband spread spectrum is not considered by the FCC before it auctions off large chunks of the PCS bands, the industry will undergo major delays in the development of a very significant and efficient way of communicating.

d. Fast-Paced Technology Evolution

A short product use cycle can be a market inhibitor when vendors in a chaotic market like wireless are unable to keep up with technology changes and/or cannot achieve consensus among themselves regarding a key product or service "standard."

Also, vendors that are undercapitalized or unable to successfully drive a technology to reasonable market share will find themselves looking for more capital and are more likely to merge or partner with another entity.

e. Security

Because the air waves are easily monitored by others, security may become of greater interest, especially when sensitive customer data may be "sent" without encryption. Companies may want to consider the viability of securing the information before sending sensitive data. It may be considered illegal for certain cellular conversations to be monitored, but many people have access to receivers that can easily monitor those "conversations."

f. Health Hazards

In early 1993, a widower claimed that his spouse had died of cancer caused by a portable cellular telephone. Although the cellular industry immediately produced a number of studies that showed no direct risk from the use of cellular telephones, several industry experts concluded that no studies had been done to determine if there was a health risk linking cancer to cellular telephone use. (A number of studies have been conducted since the early 1960s.) The Cellular Telephone Industry Association (CTIA) announced plans to spend $25 million in research over the next five years and sponsor government-led research into the area in question.

One year later, the formal study is still under development by CTIA's Science Advisory Group. The study's planning stage document was to be completed and released in July, 1994.

As for government participation—let alone leadership—the Food and Drug Administration issued a recent statement saying it still could not assure users that cell phones are safe and has made moves to distance itself from the trade group. This occurred after CTIA incorporated FDA comments that were out of context into a press packet, implying that cell phones are "safe." The FDA went on to say that "There is not enough evidence to know for sure, either way. It is simply too soon to assume that cellular phones are perfectly safe, or that they are hazardous—either assumption would be premature. This is precisely why additional research is needed."

Discussions with other industry experts as of press time indicate that they have heard nothing further regarding the CTIA study. The FDA now says that while it has no funds or plans to conduct

any tests of its own, it is interested in the outcome of the CTIA study.

Perhaps the quietness of the situation is attributable to a lack of new research information and the absence of any situation that would promote further concern from the public. In light of the lack of formal studies, it would be prudent to monitor whatever research may be forthcoming.

Market inhibitors are summarized in Exhibit V-4.

Exhibit-4

Wireless Market Inhibitors

- Unfavorable Regulation
- Lack of Radio Spectrum
- Lack of Standards
- Security
- Health Hazards
- Fast-Paced Technology Evolution

F
Market Direction and Expenditures Forecast

1. Market Direction

The potential for the wireless market is positive, without doubt. User demands for new ways to make businesses more effective, coupled with vendor needs to gain a significant foothold of market share, will provide a strong impetus for significant growth through the end of this century.

2. Wireless Growth

Estimating this expansion is a difficult task. However, the following projections are indicative of a combined assessment, as a consensus of industry sources. Today's overall U.S. wireless market represents about 15% of the telecom market, with growth in wireless subscribers of an estimated annual 30%; wireless will reach nearly 25% of the telecom market by 2000.

a. Cellular

The conversion to wireless communications is moving at a very rapid pace. There were more than 13 million cellular telephone users at the end of 1993. The cellular market is growing at about a 40% annual rate, placing the number of forecasted users at 40 million by the year 2000.

b. Cellular/PCS Subscriber Revenues

The cellular and PCS markets represented about $12.5 billion in 1993. Assuming market growth to 40 million subscribers by the year 2000, and current monthly prices of $80/month, dropping about 50% through 2000, total revenues would increase to about $19 billion. Some projections suggest that the user count might climb as high as 85 million by 2000, resulting in revenues of about $40 billion.

c. Paging

The paging market had 18.5 million users at the end of 1993. This low-cost communications alternative is evolving at a 23% rate of growth and is expected to reach 20 million users by the year 2000.

d. SMR (Two-Way Mobile Dispatch)

Two-way communications dispatch had 15 million users at the end of 1993 and is expected to grow to 20 million users by the end of the century.

e. Mobile Data

At the end of 1993, there were a million users of mobile data communications. Some industry experts are forecasting huge growth in this area, placing the number of users at 13 million by the year 2000. INPUT more conservatively estimates that the number of mobile data users will be closer to 8 million by the year 2000.

f. Cellular Penetration

Penetration in 1993 for cellular telephone service was about 6% of total potential users, having grown a full 100% since 1990. Market projections suggest this pace to be increasing and may attain 20% to 25% penetration by the end of this century.

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Vendor Trends and Issues

A
Competitive Climate

INPUT conducted a number of vendor interviews to determine vendors' understanding of significant trends and issues occurring in the wireless marketplace (see Exhibit VI-1). Though it is important to keep in mind that there are a number of diverse vertical markets that make up this industry, the common thread among them is that all of them are moving very fast.

Exhibit VI-1

Key Business-Driven Trends and Issues

- Understanding Users' Needs
- "Co-opposition"—Risk-Sharing Alliances
- FCC Regulations
- Standards
- High Cost of Capital and Competition
- User Privacy Issues
- Wild Card Health Issue

1. Key Business-Driven Trends and Issues

a. Understanding Users' Needs

The greatest concern of vendors is to understand what users need. As will be noted in the user interview section of this report, wireless is in the process of invention. As the industry matures, a number of forces are driving the requirements evolution. The industry is following a classic cycle of maturity, except that it is

occurring more rapidly than most. Markets are being developed by vendors inventing new technologies, coupled with users who identify new tools for ways to do business with greater effectiveness. Both sides are creating breakthroughs to the point that change is constant.

The good news is that users are becoming more knowledgeable and are better able to articulate their requirements. As this educational process continues, more solution selling will occur.

b. "Co-opposition"—Risk-Sharing Alliances

To mitigate the high risks associated with this fast-paced industry, vendors are continuing the process of partnering and alliances, although some complained that the alliance process is not going fast enough. One vendor aptly coined the phrase "co-opposition," referring to these necessary love-hate relationships. Vendors must build these relationships amongst themselves so as to have a viable base of network software that runs on the latest piece of hardware, supporting the evolution of new features that are constantly driving this market. Other examples, among many, are the big-picture convergence between the telephone and cable TV industries; and the fact that long-distance companies apparently want to ally themselves with wireless vendors to circumvent the local access charges of local exchange carriers (RBOCs). (See section 1.e.)

c. FCC Regulations

The decisions of the Federal Communications Commission will have a major impact to the potential number of wireless carrier industries. The auctioning of the PCS frequency spectrum allocations to as many as seven nationwide entities for as much as $10 billion is drawing much attention. What is crucial to the process is that the FCC is intent on fostering competition and growth in the wireless marketplace—the antithesis of regulation as the carriers have known it. And there are a lot more than seven companies that plan to enter the bidding process.

Timing is another major issue for those planning to participate in the PCS marketplace. Delays incurred by the FCC in bringing about the auction process may result in large market penetration losses by the new PCS players. Existing wireless services such as cellular, private packet networks, and ESMR systems can and

will produce services in the very near future that are similar enough to displace a significant PCS foothold.

It is important to keep in mind that upwards of 40 MHz of the new PCS band has been set aside for nonlicensed services such as local-area networks, private branch exchanges, and other services. These companies should be shielded from the effects of the pending auction.

d. Standards

This area will continue to be a hot spot as the wireless industry grows. Of major import is the fact that the cellular industry is divided in its move to digital multiplexing. There are two digital multiplex standards that will help the industry gain more channel capacity from its fixed number of frequencies, expand on the number of features available, improve security of conversations, and reduce the noise and interference that go along with analog radio transmission.

TDMA, or Time Division Multiple Access, offers a seven-fold channel capacity improvement over conventional analog systems, is supported by McCaw Cellular and Southwestern Bell, and has the blessing of the Cellular Telephone Industry Association (CTIA). Also, it is already up and running in a few places around the country.

CDMA, or Code Division Multiple Access, offers up to a twenty-fold channel capacity over conventional analog systems, is being considered by several other large cellular operators including Air Touch (Pacific Telesis), shares the blessing by the Telecommunications Industries Association (TIA) with TDMA, and is operating in field trials.

The good news is that most cell phone manufacturers have designed their radios to accommodate either standard. Also, both standards are developing data transmission capabilities.

e. High Cost of Capital and Competition

To mitigate the risks of development, vendors are sharing the high costs of development for potentially short life cycle products through partnerships and alliances. Having more than one player, and especially financially solvent players with long track

records, is very helpful when a company goes to its bank or investors for development capital. Coupled with the potentially short life cycles of these products is the ever-present competitive pressure. Vendors have to be, to a certain extent, paranoiac, to always anticipate what the competition may be doing with its latest mouse trap, release 2.0.

f. User Privacy Issues

From a user privacy perspective, what would you do if you had the ability to communicate with anyone at any time—and they had the ability to do likewise? If you think a pager is bad as an "electronic leash," wait until you try a full-featured PDA! Companies are becoming more concerned about the social implications of being reachable under any circumstance. This ubiquitous communications capability will most assuredly add to the list of human stresses. Wireless represents a potential encroachment on a user's personal life, as well. Included in this area is the impact of simply receiving an unsolicited call—one that you must pay for.

g. Wild Card Health Issues

Vendors acknowledge that the health issues linking cancer to portable devices induces a real wild card into the scheme of things. With a marked trend toward increased sale of portable (handheld) over mobile devices, and a huge number of yet-to-be-built portable (handheld) PCS devices, there is potential for the undoing of the portable market. Today's portable cellular user has shrugged off the undefined potential health hazard or traded it for the benefits of ubiquitous communications.

2. Technology Issues

Technology issues are shown in Exhibit VI-2, below.

Exhibit VI-2

Technology Issues

- Integration
- Move to digital
- Global deployment
- PCS will have to do what cellular does

a. Integration

There is a trend to integrate voice, data, and messaging within one service or device. Its roots are at the carrier level, where we see the cellular, SMR, and satellite industries merging these three media forms under the term "enhanced" cellular, or ESMR, as it is now called. It is interesting to note that PCS will include these enhancements, too. The current strength of data communications provided by the private packet network carriers will probably fade as more of these voice and data enhancements come to market. Look for wireless video to become more prevalent as an enhancement, later in the decade.

b. Move to Digital

Although digital multiplexing has already been reviewed as a standards issue, it is very much a changing technology issue. As these multiplexers are deployed, there should be a reduction in the cellular industry's capacity problems (busy signals) occurring in major metropolitan areas. Included in the list of benefits will be clearer and more secure conversations.

Along with the digital multiplexing activities is a move by the cellular industry to roll out an improvement in data carrying capability called CDPD, or cellular digital packet data. CDPD addresses the current problems of analog data transmission that are manifest as reliability and complexity. Anyone who has talked over cellular telephone systems while moving has experienced the types of interference that are common to mobile radio transmission. Data transfer is less forgiving under these circumstances and should improve considerably. Also, complexity comes into the picture during call setup. Most of today's modems have been designed to expect and utilize telephone dial tone as part of the call setup process. But cellular telephone has no dial tone, thus requiring a work-around device or acquisition of modems (and software) that compensate for this problem. And because cellular is a different medium, there are new protocols that do a much better job of addressing wireless data transmission.

c. Global Deployment

Although this report is focused on the domestic issues of wireless activities in the U.S., it is important to note that wireless is very

much alive and well in other parts of the world. In fact, many of the RBOCs and long-distance carriers are active participants in cellular, cable TV, *and* PCS systems in other countries.

Look for international influences and positioning among the players, some of them being foreign carriers, as the wireless industry continues its growth. One of the more obvious players is BT (British Telecom) which made a sizable $4.3 billion investment in MCI last year.

d. PCS Will Have To Do What Cellular Does

If PCS is to carve out a successful market after its nearly two-year buildout, it will have to do whatever the cellular industry does—and do it better. Perhaps this is a somewhat obvious position, advanced by the cellular industry, but it does make sense. PCS vendors know that it will be an uphill fight for market share, as both the cellular and ESMR industries will be well along in their product and service positioning.

B
Trends in Wireless Growth

Promoters of wireless growth are summarized below, in Exhibit VI-3.

Exhibit VI-3

Key Growth Promoters

- Emerging technologies pressure competitive prices
- Cellular industry maturing
- Product availability and market awareness
- PCS will cause market expansion

1. Key Growth Promoters

a. Emerging Technologies Pressure Competitive Prices

As these new technologies come on line, there is little incentive to try a more expensive service, if the current system already goes many more places than the new guy on the block. This is a mobile world, and geography—"coverage"—is a primary concern. That

isn't to say that a new handheld terminal, for example, may push the price barrier. But due to short product life cycles, users will probably be on the winning end of many deals.

Prices will also come under pressure as the volume in wireless activities increases and as wireless phones begin to be substituted for the hardwired variety. This, coupled with the benefits of "partner-developed" hardware and software, will lend further support to competitive pricing.

b. Cellular Industry Maturing

The maturing of this industry is having an effect on how it is sold to customers. Some vendors are beginning to focus on the promotion of service issues to differentiate products. Improvements in seamless network coverage and roaming are still important.

c. Product Availability

The introduction of each new product into the marketplace should help to spur the wireless industry. The market should experience growth as users become more aware of the features and benefits of wireless services.

d. PCS Will Cause Market Expansion

The rollout of new personal communications services will generate significant expansion within the entire wireless industry. As previously noted, non-PCS vendors will be even more aggressive as PCS draws near, defending their products and services through various forms of differentiation.

2. Key Growth Inhibitors

Inhibitors to wireless growth are shown below, in Exhibit VI-4.

Exhibit VI-4

Key Growth Inhibitors

- Delays in product/service rollout
- Market evolving too rapidly
- Shakeout inevitable
- Cost of equipment and services
- Technology integration and compatibility issues
- Wild Card health issue

a. Delays in Product/Service Rollout

Vendors share a primary concern that products and services will be delayed as a result of FCC regulatory delays. These concerns have to do with the delayed allocation of frequency spectrum, size, and type of transmission methodology; resulting in regulatory delays and subsequent loss of market share.

Vendors are also concerned about the conflicting standards that exist, as well as the lack of definitive standards due to the rapid growth of the industry. Getting the entire industry to sanction a specific digital multiplex scheme would be a good start. But there are other spread-spectrum schemes that may put continued pressure on this transmission issue.

b. Market Evolving Too Rapidly

Another area of great concern to vendors is the rapid pace of the wireless market. The entire product development life cycle must occur more rapidly. This incurs additional risks at the various stages of bringing a product or service to market. Obviously, a substantial amount of time should be set aside for these activities, causing vendors to look for more ways to optimize the development cycle.

c. Shakeout Inevitable

With all this development and market expansion activity, a certain amount of vendor shakeout is bound to occur over the next few years. Some of the keys to survival include choosing the right standards, building the right alliances, and correctly interpreting the regulatory and free market processes.

d. Cost of Equipment and Services

Keeping the costs of equipment and services in check is a never-ending problem. It may be a common lament, but it certainly can have an effect on market expansion.

e. Technology Integration and Compatibility Issues

The introduction of any new product in this technical area requires the careful review of how the product will be integrated into a given service and forces an assessment of compatibility issues. This is particularly difficult to accomplish, given the rapid evolution of the industry and lack of standards.

f. Wild Card Health Issue

Should more health issues be raised, there could be a significant slowdown in development of the portable handheld devices used in the cellular and PCS markets.

C
Market Strategies

INPUT asked vendor respondents for their views on product market strategy and how they plan to differentiate themselves from other competitors. Results are summarized in Exhibit VI-5.

Exhibit VI-5

Vendor Market Strategies

- Awareness of Fast-Paced Marketplace
- Know What Users Want
- Partnerships—Co-Opposition
- Seamless Networks (Carriers)

1. Awareness of Fast-Paced Marketplace

Staying ahead of this fast-paced market is a real challenge for vendors. With technologies evolving so rapidly, success requires on-target thinking to zero in on where a company should be and how it plans to get there. Strategic planning addresses the following areas:

- Rapid evolution of technologies—staying aware of the potential
- Technologies creating marketplace—implications to our product line
- Short product life cycles and development time to market

2. Know What Users Want

Producing meaningful products and services for users requires definitive market research about the potential value of a given application. The vendor respondents noted the following strategic points for new product development; products should:

- Provide a competitive edge
- Meet TQM requirements
- Empower the user
- Be affordable

3. Co-Opposition—Partnerships

Another important strategy by which to mitigate risks is to create alliances and partnerships with other companies that either complement or have the same general goals for the development of a product or service. The goals do not always have to embrace a specific technology and may be more in line with the provision of financial investment and stable corporate image. As the term "co-opposition" implies, sometimes these alliance relationships are the antithesis of what one might expect.

4. Seamless Networks (Carriers)

The strategic objectives for the cellular and PCS companies are to provide a wireless network that is ubiquitous and simple to use. A strategic goal for cellular providers is for subscribers to be able to drive across the country on the main highways, and through the functions of "roaming" be able to not only generate but receive calls without interference and dropouts.

PCS vendors also plan for seamless networks, but on more of a metropolitan scale. Their strategic plans focus on differentiating themselves from cellular through product quality, pricing, and

new applications not currently available from the cellular industry, such as one-number access.

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VII

User Trends and Issues

INPUT contacted a number of users who were either contemplating or had actually installed wireless systems. The following information summarizes their insights into the industry and notes their needs, concerns, and strategic issues. As one user put it most it most aptly, "We're getting the industry invented."

A
User Trends

1. Wireless—The Automation Enabler

There used to be certain functions that just couldn't be automated because the user required a hard-wired "umbilical cord" to a processing device. Until recently, companies found it very challenging when it came to the automation of those who perform their working functions away from a traditional office setting.

Users are seeing a significant change in the way information is collected and processed.

- Functions that were once repetitively performed as manually recorded transactions and subsequently summarized on a large mainframe as monthly performance/exception reports are now performed on a handheld computing device as real-time transactions.

- Functions formerly performed through a continuous process of telephoning numerous individuals to schedule their daily activities and coordinate the results and follow-on scheduling have been replaced with alpha-numeric pagers and voice mail.

- Functions that required a constant flow of telephone calls from pay phones back to the dispatcher's office, manually coordinating the dispatch of transportation and flow of freight movement, are now performed through mobile computing devices.

Wireless technology is now enabling automation of a wide range of tasks performed by those who work outside the office.

2. Improvements in Customer Service

Half of the respondents have implemented a wireless solution to improve customer service. This tends to confirm the recent direction in business to meet or exceed the customer's needs. Wireless seems to have found a niche in providing real-time status information about the disposition of shipments and overnight mail that is in transit. Whether the result of repetitive sales advertisements on TV or an inherent desire to know the status of a delivery, wireless is producing the needed results on a real-time basis.

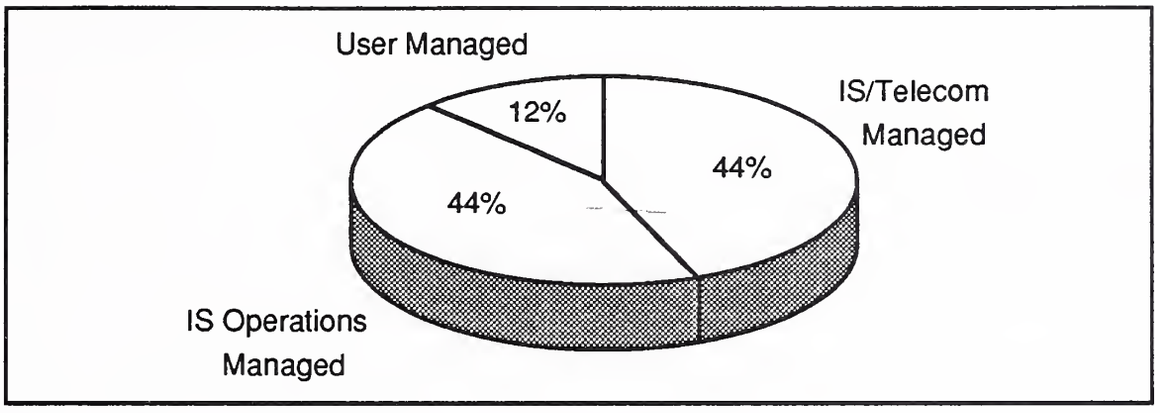
3. Wireless Rollout Plans

All of the respondents indicated that their implemented and pending wireless applications are mission critical. This is a very significant point. All of the companies determined that the wireless solutions of today, and those that may be available tomorrow, are capable of meeting critical operations criteria.

Eighty-eight percent of the respondents say that users rely on their information services and telecommunications departments for selection and implementation of wireless projects (see Exhibit VII-1). This is a strong indicator that users recognize the technical complexities of these projects and prefer that the project development be coordinated through information services. Also, almost half of the wireless applications will use some form of client/server architecture.

Exhibit VII-1

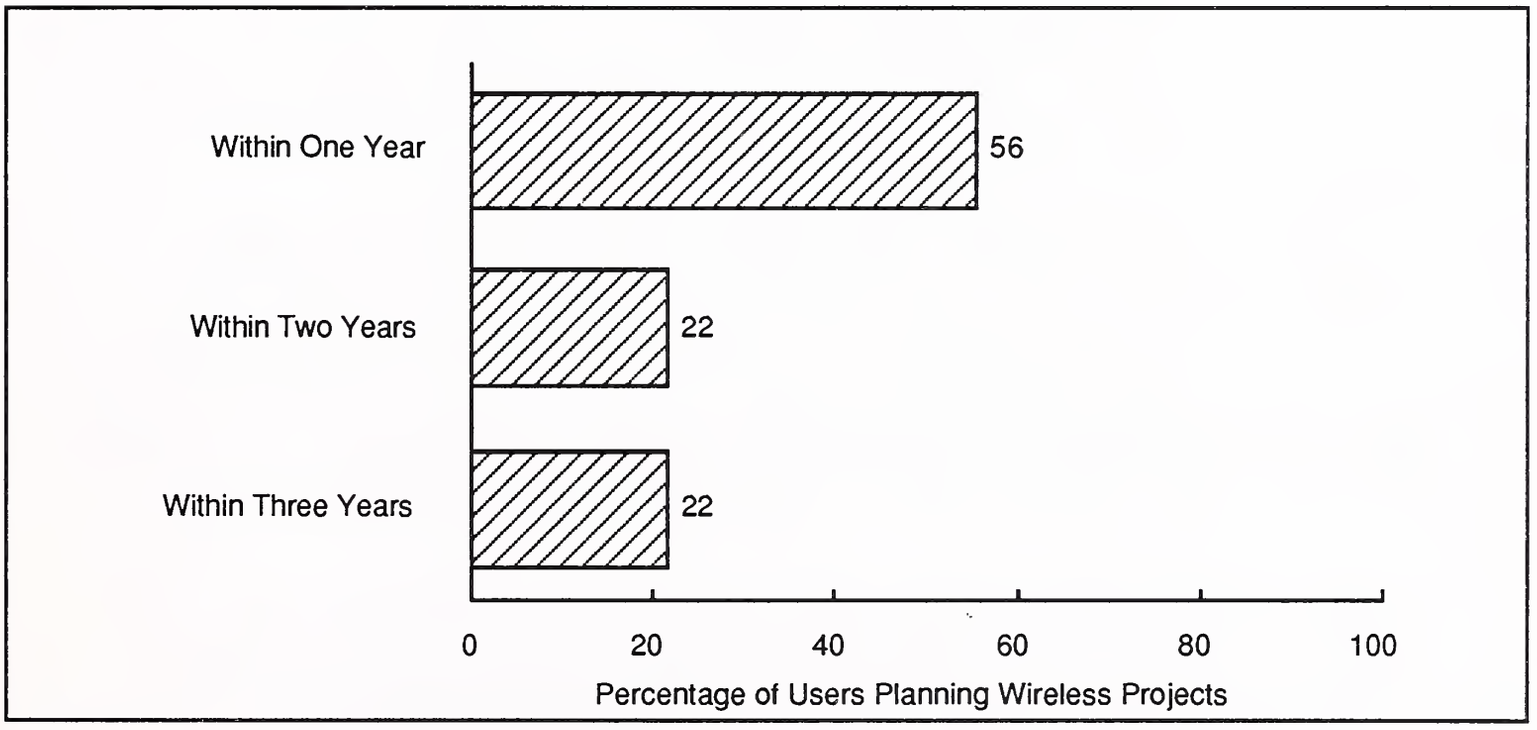
Project Management Responsibilities



Fifty-six percent of the respondents are planning new or additional rollouts of wireless applications within one year, as shown in Exhibit VII-2. This emphasizes the fast rate of technological change and absorption in this market.

Exhibit VII-2

Project Rollout Schedules



4. Strategic Benefits

Interviewees were asked why their companies had decided to move to a wireless solution. All of the respondents said that there was a clear administrative benefit. Eight-three percent saw user

benefits in wireless applications. And one-half of the companies saw the wireless application as a competitive weapon.

B
User Concerns

1. No One-Stop Shopping

The majority of applications required multiple vendors to implement wireless solutions. Short of local-area networks, there was no single vendor that could do it all. This was especially true when companies prepared for a nationwide wireless solution and found, at first, that cellular companies were more independent and required additional coordination. The private packet companies like Ardis and RAM Mobile Data had centralized coordination, but did not have the required geographical coverage.

Forty-four percent of respondents indicated that they are planning to use either outside vendors or systems integrators in the development of wireless applications. This is certainly true for organizations that require wireless systems implementation on a large, multi-location or national level.

2. Network Interoperability, Security, and Voice Capability

Most of the respondents thought network interoperability and network security to be very important. Although interoperability was not always an immediate concern, it was considered to be an eventual "must," since the consensus was that all of a company's networks will come together in the not-too-distant future.

Network security issues are an ongoing consideration and have become more focused, especially when "outside" wireless solutions are contemplated. However, none of the companies made note of any plans to use some form of encryption.

Most of the respondents said that voice capability, integrated within the wireless terminal, was not very important. Though this is certainly worthy of note, it may be due to an aberration in the user sample, as both Eo and BellSouth now include voice capability in their terminals. (Note the number and divergent types of terminals described in Chapter IV, Section G, "Wireless Terminals.")

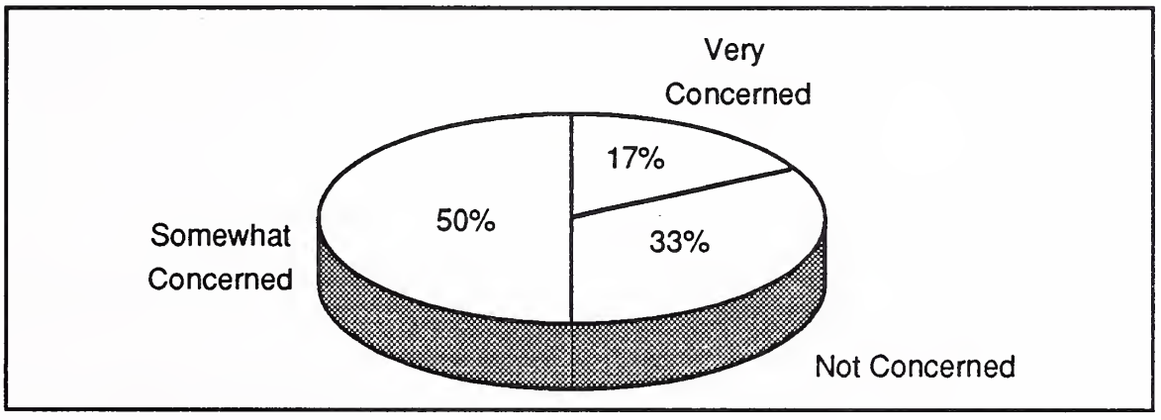
3. Health Hazard Implications

The interviewees were asked how concerned they were, if at all, about the health hazard (cancer) potentials of wireless transmission. Responses to this question indicated a limited concern about wireless health hazard implications.

One-half of the respondents were somewhat concerned; one-third indicated they were not very concerned; and only seventeen percent said they were very concerned.

Exhibit VII-3

Health Hazard Concerns



A respondent indicated that, as part of their acceptance criteria, they had conducted excessive radio transmission testing to assure worker safety. One of the vendors was asked to go back to the drawing boards to reduce radio emissions that were considered above acceptable levels.

Interviewees indicated that if certain health hazards did become an issue, they would fall back to hard-wired architecture or limit use to nonhazardous areas.

What is important to note is that prudent use of portable radio devices should be encouraged in light of what is not yet known. The FDA (Food and Drug Administration) still has no conclusive evidence and will sit squarely on the fence until some truly unbiased test results have been evaluated. There have been a number of studies reviewing the implications of excessive radio frequency power transmission as well as excessive electro-magnetic field (EMF) phenomena since the early 1960s. The ANSI (American National Standards Institute) standards for radio frequency power thresholds have been lowered, twice. But there is still no clear answer as to whether certain radio

frequencies do cause or allow cancer to grow. It may take several years to accurately identify conclusive evidence.

VIII

Key Industry Applications

The following applications are indicative of the process that one might take in development, selection, and implementation of a wireless system.

A
Transportation Industry

1. Problem Definition

A large over-the-road trucking company is experiencing difficulty in dispatch coordination and load distribution controls. Being in the liquid chemical distribution business, drivers usually start the day at the "yard" unless they are on an extended delivery, but in either case, they receive their dispatch and delivery manifests from the local dispatch office. As the day progresses, several problems occur: changes in delivery are made to support customer needs, bad weather conditions cause a detour, a trailer's brakes fail on a mountain road. When these situations occur, drivers must check in with the dispatcher at each customer's site or plan on stopping at a roadside telephone. In the case of a major breakdown they must rely on the highway patrol or very possibly the trucker's CB radio—if the driver has one.

2. Application Description

To meet these variable situations, the IS department looks into the use of wireless services to automate the dispatch and load control areas. Feedback from their user group, including several truck

drivers from various regions, indicates the following requirements:

- All dispatch exchanges will be performed through a PC-based mobile terminal that emulates an extension from the company's ethernet LAN.
- The "on-board" mobile computer receives information from a sensor device that reports on the various engine functions and trailer tank capacities.
- A bar code device also interfaces with the mobile computer to scan dispatch shipper and initial invoice documents.
- Capacity sensors are added to all tank trailers.
- Voice transmission is considered very important—especially during emergency situations.

3. Vendor Selection

It soon becomes evident that several of the potential wireless carriers do not have adequate coverage to service the more remote areas that the company's trucks pass through. As a result, SMR and private packet networks are eliminated.

Three alternative carrier systems look promising:

- Cellular
- Satellite
- Meteor burst

Cellular is subsequently eliminated because it, too, is unable to provide service to certain rural areas. When the trucking company learns that it can also have vehicle location through the satellite vendor, the meteor burst carrier is also dropped from further consideration.

4. System Benefits

The trucking company will derive several benefits from its new wireless installation.

- All dispatch manifests and load control activities are now automated.
- Alternate routing, road information, and truck performance, including estimated time of arrival, are now available on a real-time basis.
- Vehicle locations are constantly tracked through the satellites.

Re-engineering a business process has brought the company a value-added benefit. Sensors have been placed on all customer storage tanks. A co-located cellular telephone calls the company's central computer system when the sensor detects a drop below a certain threshold.

5. Summary

It may be several years before the company breaks even after implementing its new wireless system. Daily operational savings are fairly significant, but the company will have to pay for a major coding effort to rewrite its aging data base software system. Soft savings are immediate, with the real-time improvements of dispatch and delivery and the significantly enhanced automation of customer service.

B
Health Care

1. Problem Definition

A health services company needed to coordinate and keep track of its numerous medical teams, strategically located throughout the country. Scheduling, logging of hours, and reporting were critical to the effectiveness of the business. All of the individuals who would make up a given team would need to communicate with their supervisors, who were also in transit quite often.

2. Application Description

The company found that some of these problems were rectified through a combination of interactive voice response (IVR) and remote voice mailboxes. But, when it became necessary to reach

team members immediately, it was still confronted with the problem of having to reach individuals.

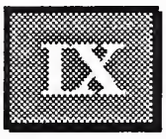
3. Vendor Selection

Use of PDAs was considered initially, but was ruled out on the basis of excessive costs incurred in recoding data base information. (However, PDAs will be considered for applications in the future.) Cellular telephones and paging seemed to be the best alternative because all team members worked in major metropolitan areas. But cell phones were considered too expensive in light of the potential for significant increases in telephone costs; team members had the propensity to respond through the most expeditious device available at the time.

Ultimately, alpha-numeric paging was selected as the best option. A software package was selected to integrate the company's E-mail system with the paging company's interface requirements.

4. Summary

Now, the company's team members can receive specific alpha-numeric paging messages almost immediately. Because it is specific information, the response can be prioritized by the recipient. The company will consider two-way messaging when it becomes available because of the value of knowing whether or not the message was received.



Conclusions, Recommendations, and Opportunities

A
Today—Inventing The Industry

1. Big-Picture Perspective

Keeping an eye on the larger scenarios of the overall telecommunications industry will be beneficial to those who participate in the wireless arena. Staying aware of the goals and objectives of these players, and potential players, will help to determine the best position to take when it comes to wireless products and services. Telephone and cable entities will continue to have local access limitations of a technical and regulatory nature that make the wireless world more lucrative. These companies see the potential in wireless and some are willing to bet (invest) significant sums at the PCS auction to grab market share.

2. Consolidation of Services

Simplification may become a primary force in the consolidation of various wireless services. The company or companies that come up with a single handheld and/or mobile device that integrates voice, data, and paging will wield considerable force. The ESMR industry appears closest to this goal, although arguments can be made for a cellular solution that might not be too far in the future.

3. Alliances

Alliances will tend to mitigate development risks. This partnering can be beneficial not only in the development of technical systems, but in financial investment and enhancement to corporate image.

4. Systems Integration

The wireless industry should continue to be fertile ground for systems integrators. Vendors may find some additional alliance opportunities through these channels.

5. Need for Open Standards

Many standards battles are ahead for the wireless industry. Standards committees must be flexible enough to allow breakthrough technologies to develop and gain a foothold in the marketplace. Users (and vendors) need to continue to apply their influence in the evolution of open standards that allow for such breakthroughs.

6. Ecology and the Finite Medium

Vendors and regulators alike should be on a continuous quest to plan, develop, implement and maintain more efficient radio transmission systems. If the radio spectrum is mismanaged or poorly maintained, it has the potential to cause major disruption to other users in multiple parts of the radio spectrum. Any technology or spectrum usage plan that works toward these goals should be given special consideration by the FCC.

7. Health Issue Wild Card

The wireless industry will experience a serious setback if and when conclusive evidence is produced that handheld wireless devices do cause or contribute to causing cancer. It may suffer another temporary setback, as it did in 1993, unless a number of non-vendor-sponsored epidemiology studies prove that the repeated use of close proximity radio transmissions is not harmful to humans.

8. Companies and Technologies to Watch

- MCI and Nextel—Last fall, MCI scrapped its 150-company PCS consortium to invest in and develop its services more expeditiously over ESMR.
- Metricom—Paul Allen, Microsoft co-founder, just made a sizable investment in this radio network provider.
- Steinbrecher Corporation—Donald Steinbrecher has developed a micro-cellular telephone site the size of a briefcase, which uses frugal spread-spectrum transmission technology. Cell sites could be available at 10% of current costs.
- Electric utilities—These organizations have petitioned the FCC to allow them to participate in providing wireless and "hardwired" fiber optic telecommunications services.
- First Virtual—Ralph Ungerman claims he can network PCs using reduced speed ATM (Asynchronous Transfer Mode) at costs that are 20% of the competition's. PCs could therefore be using full-motion TV much sooner than expected.

B
The Near Future—Two to Three Years

1. Shakeout

A shakeout in the wireless industry could occur within the next two to three years as some of the alliances falter when PCS, CDPD, and service consolidations of voice, data, and fax take their toll.

2. CDPD Rollout

The rollout of CDPD—the cellular industry's answer to data communications—is expected to be slow. Some of the problems include component delays and ways to invoice users who "roam" beyond their local areas. But, as CDPD becomes ubiquitous over the next two or three years, the private packet networks will have to scramble to keep hold of a waning market share. The assumption is that cellular coverage will continue to be superior to the PPNs'.

3. PCS Rollout

The rollout of personal communications services in the 2 GHz area will take upwards of two years to implement from the time the FCC gives permission. It entails not only the implementation of many micro-cell sites, but the relocation of numerous microwave users to other frequencies. Also, the government is anticipating that wireless is going to be a big hit and, as a result, has asked the FCC to identify an additional 200 MHz for future applications; this, too, will have its user relocation problems.

C
The Future—Five to Seven Years

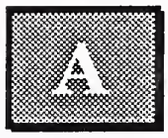
Most of us should be able to receive "dial tone" from at least three different sources—all of which will offer a wireless solution:

- Local Exchange Carriers
- Long-Distance Carriers
- Cable TV Carriers

Each person will be assigned a single telephone number, doing away with separate numbers for different offices, pagers, car phones, etc. Universal roaming will be in place as well.

Wireless PCS and cellular networks will become integrated, eliminating the need to carry multiple telephones. A wireless call (whether voice, data, or paging) can be generated through a micro-cellular (PCS) metropolitan network or a cellular network and subsequently interfaced to local or long-distance carriers. This is conceptually accomplished in much the same way that today's LANs interconnect to MANs and WANs. The futuristic phone call will be accomplished through integrated network switches and enabled through Synchronous Optical Network (SONET) protocols of the Asynchronous Transfer Mode (ATM).

The handheld computing device will support voice, voice messaging, enhanced paging, data access/retrieval, e-mail, and fax including text-to-speech. Full-motion video still may not be radio spectrum efficient to incorporate into a portable device.



Terminology

Carrier Systems - Companies responsible for the transmission of various types of media, e.g., telephone, cable, wireless, or LAN

CDMA - Code Division Multiple Access - A digital multiplexing technique used to increase the number of voice conversations in a cellular telephone system

CDPD - Cellular Digital Packet Data - Cellular data transmission system that is designed to improved data transmission over cellular systems

Convergence - Used in reference to the merging of major parts of the telecommunications industry, e.g., RBOC and cable TV, or cellular and long-distance companies

Co-Opposition - Alliances and partnerships that are formed between vendors to share the risks of development. These vendors are competitors in other environments.

LAN (Local-Area Network) - A medium- to high-speed data transmission network, usually installed within the confines of a building or campus, that passes data through a variety of media including coaxial cable, fiber optic, twisted pair (copper wire), and various wireless radio configurations

LEO (Low Earth Orbit) - Requires a larger number of geo-stationary satellites (approximately 50 to several hundred) which facilitate low power, cellular-like services, providing very broad geographical coverage

PBX - Private Branch Exchange - An on-site telephone switching device for users now employing wireless cellular-like technology as well as traditional twisted pair wiring to its telephone handsets

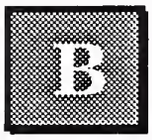
PPN - Private Packet (Radio) Network - A nationwide network of multipoint radio towers, located in major metropolitan areas, that pass relatively low-speed data communications information to and from mobile computing devices

Radio Spectrum - Defines and divides a large number of frequencies, measured in Hertz, by frequency groups or bands. For instance, the cellular telephone industry is allocated certain portions of the 800 megaHertz (MHz) band for its operation.

SMR/ESMR - Specialized Mobile Radio/Enhanced Specialized Mobile Radio - Currently a large number of local voice-dispatch networks for taxis and truckers, it is now in the process of converting to a nationwide cellular-like alternative using a new digital process supporting voice, paging, and data transmission

SONET - Synchronous Optical Network - A set of multiplexing formats and protocol specifications for high-speed digital fiber optic communications

TDMA - Like CDMA, Time Division Multiple Access is a digital multiplexing technique used to increase the number of voice conversations in a cellular telephone system



Wireless Players

Exhibit B-1

Wireless Systems	Vendors
Cellular	RBOCs, ATT/McCaw, GTE, Sprint
Specialized Mobile Radio (SMR)	Nextel (MCI/Comcast/Motorola/NTT), CenCall, Dial Page
Personal Communications Services (PCS)	RBOCs, GTE, IXCs, CATV, and start-ups e.g., Metricom
Private Packet Radio Networks	Ardis, RAM Mobile Data
Network Software	Advantis, Airsoft, ATT, Lotus, Nettech Radiomail, General Magic
Enhanced Paging Service (EPS)	RBOCs, EMBARC (Motorola), PageNet, Skytel (Mtel), Nationwide Wireless Network (Microsoft/Mtel)
Satellite & Low Earth Orbit (LEO)	American Mobile Satellite, Geostar, Orbital Comm., Qualcomm LEO: Iridium (Motorola/Consor), Teledesic (Microsoft/McCaw)
Access Devices* * Telephones//Terminals//Modems	ATT, Motorola, NEC, Oki// ATT, Apple, BellSouth, Ericsson-GE// ATT-Paradyne, Intel, Megahertz
Local-Area Network (LAN)	AT Schindler, DEC, InfraLAN Tech., RDC Comm, Motorola, NCR
Private Branch Exchange (PBX)	ATT, Ericsson, NTI, Rolm-Siemens
Meteor Burst	Broadcom, Meteor Communications, Pegasus Message
Broadcast TV and Radio	Cue Paging, Skytel, Telefing
Other Private Radio Services	Numerous private industry and government systems

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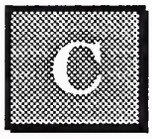

User and Vendor Questionnaires

Wireless Telecommunications—User Questionnaire

I. User Description

1. Name_____

   Title_____ Tel. #_____

   Fax # _____

2. Company _____

3. Address _____

   _____

4. What are your company's gross revenues for this fiscal year?

   a. $ _____

   b. Current domestic % of market? _____

   c. Current international % of market? _____

5. What is your company's IS organizational structure?

   a. Centralized Corporate MIS? _____

   b. Distributed Divisional MIS? _____

   c. Is Telecommunications a separate entity? _____

   d. Does Telecommunications report into MIS? _____

e. Which areas are outsourced and why?

_____

_____

II. Wireless Systems and Applications Information

6. What are the major objectives of your information systems/telecommunications department(s) over the next 2 to 3 years?

_____

_____

_____

7. Which wireless applications have you implemented in the last 5 years and why? (e.g., competitive advantage, improve user effectiveness, best return on investment, etc.) Were any of them mission critical?

Application # 1

_____

Why?_____Mission Critical?_____

Application # 2

_____

Why?_____Mission Critical?_____

Application # 3

_____

Why?_____Mission Critical?_____

8. Please describe the form of wireless architecture and vendors used in each of these applications. (e.g., type of carrier(s), terminal(s), and software, etc.) Were any of them mission critical?

Application # 1

_____

Vendors?_____Mission Critical?_____

Application # 2

_____

Vendors?_____Mission Critical?_____

Application # 3

_____

Vendors?_____Mission Critical?_____

9. Which applications do you plan to re-engineer or replace in the next five years that will use wireless technology and why? (E.g., competitive advantage, improve user effectiveness, best return on investment, etc.) Are any of these mission critical?

Application # 1

_____

Why?_____Mission Critical?_____

Application # 2

_____

Why?_____Mission Critical?_____

Application # 3

_____

Why?_____Mission Critical?_____

10. In what timeframe do you foresee making the transition to each of these wireless applications?

Application # 1

_____

Application # 2

_____

Application # 3

_____

11. Which division/department (e.g., IS, Telecom, User, etc.) will have primary responsibility for each project/application installation?

Application # 1

_____

Application # 2

_____

Application # 3

_____

12. To what degree are you looking to outside vendors or systems integrators for products and services?

Application # 1 _____% of our needs will be met by outside vendors.

Application # 2 _____% of our needs will be met by outside vendors.

Application # 3 _____% of our needs will be met by outside vendors.

13. Which form of wireless architecture are you planning to use and which vendors are you evaluating for each? (E.g., type of carrier(s), terminal(s), software, etc.) Are any of these mission critical?

Application # 1

_____

Vendors?_____Mission Critical?_____

Application # 2

_____

Vendors?_____Mission Critical?_____

Application # 3

_____

Vendors?_____Mission Critical?_____

14. What system platforms are most likely to be used (regarding hardware and operating systems)?

    Application # 1

    _____

    Application # 2

    _____

    Application # 3

    _____

15. What is your total budget for each wireless application?

    Application # 1 For this year $_____ Over the next five years $_____

    Application # 2 For this year $_____ Over the next five years $_____

    Application # 3 For this year $_____ Over the next five years $_____

16. How important is it for the wireless terminal to have:

    a. Voice capability?_____

    b. Network interoperability?_____

    c. Network security? _____

17. How concerned are you about the health hazard potentials of wireless transmission, if at all?

    _____

    _____

18. Which alternative architectures would you be likely to use if these health hazards are found to be a serious issue with wireless technology?

    _____

    _____

    _____

19. What are the most important reasons for moving to a wireless environment (e.g., user benefits, administration benefits, competitive edge, etc.)?

_____

_____

_____

20. What wireless application trends do you see in your industry over the next two to five years?

_____

_____

_____

Wireless Telecommunications—Vendor Questionnaire

I. Vendor Description

1. Name_____

   Title_____ Tel. #_____

   Fax # _____

2. Company _____

3. Address _____

   _____

4. What are your company's gross revenues for this fiscal year?

   a. $ _____

   b. Current domestic % of market? _____

   c. Current international % of market? _____

5. What are the company's past and projected revenues?

a. For 1993? $_____

b. For 1999? $_____

II. Industry Sector Trends

7. What are the key business-driven issues or trends that are affecting the wireless services marketplace? As a wireless services vendor, how does this impact your business? For instance, what impact will any pending ruling by the FCC have on your business?

_____

_____

_____

8. What are the key systems/technology-driven changes, issues, or trends that are affecting the wireless services marketplace? How is your company responding? What is this doing to your business?

_____

_____

_____

9. What else is changing about the marketplace?

_____

_____

_____

III. Trends in Growth and Strategy

10. What are the key growth promoters for wireless services? Stated another way, what are you doing to grow your business?

_____

_____

_____

11. What are the key growth inhibitors?

_____

_____

_____

12. What types of business have you lost in the last year and why?

    a. To competitors _____

    _____

    b. To other _____

    _____

13. How are other delivery modes (e.g., PCS as opposed to Cellular) and the overall trends in the information/ telecommunications industry impacting wireless services?

_____

_____

_____

14. What is your estimate of the size of your industry's U.S. market for wireless services for 1994? (e.g., revenue for private packet radio networks) $_____

15. What percent growth do you think this represents over the last year? _____%

16. What overall growth rate do you expect over the next five years for your industry's wireless services?
_____%

17. What is your product/market strategy? (e.g., How does your company differentiate itself relative to its competitors?)

_____

_____

_____

18. What specific product development efforts are currently under way at your company?

_____

_____

_____

19. What does it take to succeed?

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IV. User Referrals

20. We would like to contact and interview up to 3 of your key clients. Which companies do you recommend, who is the contact, and what is their telephone number?

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